The Culture and Consequences of Low Energy Availability in National Collegiate Athletic Association Division One Female Distance Runners: A Mixed Methods Investigation

by

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Dedication

This dissertation is dedicated to every female athlete who has struggled with an eating disorder. I hope this work begins to change the narrative for the next generation of "us".

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Preface

Chapter 2 (**Cultural and Environmental Associations with Body Image, Diet, and Wellbeing in NCAA DI Female Distance Runners: A Qualitative Analysis**) has been accepted for publication in the British Journal of Sports Medicine. The full list of authors is: Traci Carson, Troy Tournat, Kendrin Sonneville, Ron Zernicke and Carrie Karvonen-Gutierrez.

Table of Contents

List of Figures

List of Tables

ABSTRACT

Low energy availability (EA), a mismatch between caloric energy intake and exercise energy expenditure, underpins the ten physiological and psychological consequences of the Relative Energy Deficiency in Sport (RED-S) framework. This framework expands on the Female Athlete Triad (Triad) to include cardiovascular health, gastrointestinal health, metabolic function, growth and development, immune health and psychological health, in addition to tenants of menstrual function and bone health named in the Triad. National Collegiate Athletic Association (NCAA) Division One (DI) female distance runners are at high risk of low EA, given significant pressures to excel at both school and sport, in addition to risks that affect all female athletes, such as sport-specific body ideals and cultural pressures to be thin.

The purpose of the first aim of this dissertation was to describe NCAA DI female distance runners' experiences of perceived body image norms and disordered eating in their sport, as well as to capture athletes' perceptions on coach-athlete power dynamics. We completed interviews with 29 current and former female NCAA DI distance runners with current or past history of disordered eating and/or current or past history of the Triad. We completed a thematic analysis and two major themes emerged: 1) sport body ideals and body image norms and myths that persist in the sport, and 2) the power dynamic between coach and athletes. Findings revealed that sport body image ideals and the power dynamic between coach and athlete may contribute to female athlete's risk of disordered eating and body image disturbance, resulting in adverse health consequences.

In the second aim, we enrolled a randomly sampled, national cohort of 211 current NCAA DI female Cross Country runners. We collected rosters from all NCAA DI Cross Country teams and randomly sampled five women per team, this process was repeated, and email addresses were collected for each woman sampled. Sampled women were contacted via email for participation and completed a self-administered survey about RED-S consequences, demographics, disordered eating and emotional health. The purpose of this aim was to identify patterns of clustering of the ten RED-S health consequences using latent class analysis. The latent class analysis identified three distinct classes: Class 1, the "Low RED-S Consequence Class" representing 39% of the sample, class 2, the "High RED-S Consequence Class" representing 16% of the sample, and class 3, the "Anxious, High RED-S Consequence Class" representing 45% of the sample. Results highlight three unique presentations of RED-S consequences in this population.

The purpose of the final aim was to examine the association between latent class membership and bone injury outcomes, including bone stress fractures, bone fracture, shin splints, and bone bruise, in our sample of 211 current NCAA DI female Cross Country runners. We used Chi-Square tests to assess the relationship between latent class membership and bone injury outcomes ever and during college. Participants reported 122 total bone injuries over the course of their athletic careers; 57.3% of athletes (n=121) reported at least one bone injury, and 82.6% (n=100) of these injuries occurred during college. We observed no statistically significant difference in the burden of bone injury between the three latent classes. Future longitudinal studies are required to better understand temporal relationships between bone injury and latent classes of RED-S consequences.

Taken together, the results of this dissertation add novel data and findings to our understanding of RED-S in collegiate female athletes. Findings bring attention to disordered eating and the significant burden of RED-S among NCAA D1 female distance runners. This dissertation calls for the NCAA and athletic departments to take immediate action to address harmful power dynamics between coaches and athletes and to develop and implement programming to ensure early prevention and intervention of low EA and RED-S consequences.

Chapter 1

Introduction

Foundations of Female Athlete Health Research

In the late 1870's, clinicians Dr. Edward H. Clarke and Dr. Mary Jacobi called attention to the effects of physical and mental stress on female reproductive physiology.[1,2] Clarke suggested that women should be educated differently than men, under the premise that the female reproductive system would malfunction if the brain and body were "overused". Around this same time, Clarke was supported by researchers making similar claims for women in the workforce.[3,4] Supporters of gendered inclusion in education and work operated under the theory that physical and mental weakness was inherent to "normal" reproductive function in women.[5] Counter to this theory, Jacobi's work concluded that there was "nothing in the nature of menstruation to imply the necessity, or even the desirability, of rest for women whose nutrition is really normal" (Jacobi, 1876). Jacobi maintained that menstruation itself did not limit women's capacity to learn and work in male-centric environments, and that abnormalities in menstrual function were not natural and warranted further research attention.[1,2]

It was not until the late 1960's that the association between exercise and female reproductive health became a topic of scientific inquiry. Dr. Gyula Erdelyi is credited with the first, large cross-sectional study of menstrual cycles among athletes, conducted among Hungarian female athletes. This study used questionnaires, menstrual charts, and personal interviews to understand the influence of sport and physical activity on the menstrual cycles of

female athletes (n=729), and a subset of women (n=557) were asked to report changes to their menstrual cycles while participating in sport. Erdelyi's study found that only 11% of athletes reported "unfavorable changes" to their cycles, leading him to suggest that participation in competitive sport did not alter timing of menstruation, and that "we should exclude every pathologic factor which may cause these (menstrual) changes before we should consider sports as the causative factor". [6] It is important to note that the nature of sport participation was much less intensive during this decade, and it is plausible that the weak association observed between sport participation and menstruation was due to cohort, or time-period effects such that physical activity of female athletes was not in excess to that of non-athlete peers.[7]

The 1972 introduction of Title IX sparked a significant rise in female sport participation. While this law promised equal opportunity for women in sport, it was implemented without a complete understanding of how the female athlete differed from her male peers, both physiologically and psychologically.[8] In response, the 1970's and 1980's brought an increased scientific interest into health and performance in women's sport. In the 1970's, the work of Drs. Robert Malina and Waneen Spirduso strengthened the claim for an association between exercise and timing of menarche, specifically for delayed onset of menarche in female athletes.[5,9,10] In a study including female Olympic, collegiate, and high school athletes, and non-athlete controls, Malina and Spirduso reported that all athlete groups attained menarche significantly later than non-athletes (n=240) (p-value <0.001), and Olympic athletes attained menarche significantly later than collegiate or high school level athletes (p-value <0.001).[9] Beyond the impact on timing of menarche, other studies reported associations between sport intensity and disruption to menstrual cycles. Dale and colleagues reported a strong, positive association between weekly intensity and duration of running and menstrual disturbance among

women self-identifying as runners or joggers, relative to a control group of non-runners (n=168).[11] This study collected survey data on demographics, training schedules, and contraceptive history, in addition to serum pituitary and ovarian hormones, and body fat percentage (via skinfold test). Dale et al. concluded that menstrual dysfunction appeared to be a "real phenomenon" in female distance runners, and that training frequency and intensity, competitive events, weight loss, and body fat percentage suggested possible mechanisms for subtle and severe menstrual disturbance.[11] Further, Dale suggested that, because gonadotrophin levels and ovarian levels remain at low to normal ranges, this dysfunction was likely reversible via therapeutic measures, such as weight gain, decreased training, or medication.[11]

The 1980's and early 1990's delivered more science on the biologic mechanisms underpinning the relationship between exercise, disordered eating behaviors, menstrual disturbance, and reduced bone mineral density (BMD). This work was primarily introduced by Dr. Barbra Drinkwater and colleagues and further expanded upon by Drs. Michelle Warren, Paula Howat, and Robert Marcus.[12–15] These initial studies were largely limited to cross-sectional observations, not yet supported by biologic mechanisms, but importantly laid the foundation for further research on female athlete health and physiology.

Female Athlete Triad

In the early 1990's, the sports medicine community began to observe a trend in the occurrence of three interrelated syndromes - low energy availability (EA), menstrual disturbance, and low bone mineral density (BMD) - among female athletes (Figure 1.1). In 1992, these co-occurring syndromes were the focus of a consensus conference called by the Task Force on Women's Issues of the American College of Sports Medicine (ACSM), and in 1993 the Female Athlete Triad position paper was published; this position paper highlighted the "magnitude and

seriousness" of the three syndromes and called for a focus on strategies to "prevent, recognize, and treat" the Triad.[16,17] The ACSM updated this initial statement in 2007, and again in 2014, providing updated science and recommendations for screening, diagnosis, prevention, and treatment of the Triad.[13,14]

Following the ACSM's statements, the *Female Athlete Triad Coalition Consensus Statement on Treatment and Return to Play of the Female Athlete Triad* was published in 2014. [18,19] This 2014 Triad report was written and endorsed by the Female Athlete Triad Coalition and was intended to serve as a supplement to the 2007 ACSM position paper. This 2014 consensus statement included up-to-date scientific evidence to support the three health components of the Triad, as well as expanded treatment guidelines and return-to-play recommendations [20].

Relative Energy Deficiency in Sport

In 2014, shortly following the release of the updated Triad consensus statement, the International Olympic Committee (IOC) released *The IOC Consensus Statement: Beyond the Female Athlete Triad—Relative Energy Deficiency in Sport (RED-S).* Importantly, the RED-S framework aimed to provide a "more comprehensive term" for the Triad and include male athletes. The RED-S framework includes ten physical health and ten acute, performance related outcomes hypothesized to result from low EA (Figure 1.2). [21] The authors of the Triad model worry that the RED-S framework dilutes the emphasis on girls and women and downplays the clinical relevance of eating disorders, menstrual disturbances, and low bone mass. However, authors of the RED-S statement wished to expand beyond the Triad and address the harmful effects of low EA on many aspects of physiological function including metabolic rate, menstrual function, bone health, immunity, protein synthesis, cardiovascular and psychological health. There is currently controversy and a lack of clarity regarding how to reconcile the Triad

model with newer, more comprehensive RED-S models. However, the RED-S framework allows for a more holistic assessment of health and wellbeing among athletes and identifies additional and important areas of health impacted by low EA. RED-S is still in its infancy in scientific utility and biological mechanisms supporting the full framework remain to be elucidated. Therefore, the IOC has encouraged more research in the field, particularly studies with more robust sample sizes.[18,21,22] This dissertation seeks to contribute to this body of literature and scientific understanding of RED-S, with a focus on the ten physical health consequences of the RED-S framework, using both qualitative and quantitative methods.

Physiological Mechanisms

It is well established that low EA is associated with physiological dysfunction and subsequent menstrual disturbance and low BMD in female athletes.[23–32] The scientific findings of Dr. Barbara Drinkwater et al. (1986), were the first to cite low EA as the fundamental cause of the physiological dysfunction related to the Triad. Drinkwater et al. (1986) found a resumption of menses in amenorrhoeic athletes following a decrease in training combined with an increase in body weight; thus, an overall increase in energy availability.[32] Importantly, Drinkwater et al. noted that it was impossible to identify decreased training or increased bodyweight, or the interaction of these variables as the causative factor.[32]

Low Energy Availability (EA)

EA is defined as dietary energy intake (EI) minus the energy expended in exercise (EEE) divided by fat free mass (FFM). This measure represents the dietary energy remaining for all other physiological functions, after accounting for exercise.[33] Low EA is a state that occurs when one does not consume enough dietary energy to cover the energy requirements of exercise, in

addition to energy requirements needed to maintain all essential body functions.[34] Importantly, low EA can occur with or without disordered eating, or a purposeful restriction in food intake, and is characterized by a variety of harmful eating attitudes and behaviors, including a preoccupation with body weight and dieting, driven by pervasive body dissatisfaction.[35,36] Female athletes are at increased risk of disordered eating, compared to non-athlete peers, given sport-specific pressures to meet societal body ideals and the body and performance ideals of their sport. Prevalence estimates of disordered eating range from 8-17% among college women and 13- 50% among collegiate female athletes.[37,38] Reported estimates vary widely, due to the differences in the study methodology and subpopulations sampled.[38]

EA lies on a spectrum: from low EA, to suboptimal EA, to optimal EA, where the cutoff for low EA in athletes has been defined between < 30-45 kilocalories per kilogram of fat free mass per day (kcal/kgFFM/day).[39,40] This cut point for low EA was determined by the observation that the pulsatility of luteinizing hormone (LH), essential for reproductive function, was disrupted when EA dropped from 45 kcal/kgFFM/day to less than 30 kcal/kgFFM/day, and that menses returned in amenorrhoeic adult female athletes when EA increased above 30 kcal/kgFFM/day.[41] Bone resorption increases under conditions where EA is low enough to suppress estradiol production, and this suppression is reported to occur between and EA of 20-30 kcal/kgFFM/day.[39]

Menstrual Disturbance

A combination of physical and psychological stressors can contribute to hormonal disturbance and subsequent consequences on reproductive and bone health. In response to these stressors, the hypothalamic pituitary adrenal (HPA) and hypothalamic pituitary gonadal (HPG) axis down-regulate hormone production and initiate metabolic adaptation in an attempt to

conserve energy. As a result of decreased activity of the HPG axis, estrogen production decreases, and gonadotropin-releasing hormone (GnRH) and luteinizing hormone (LH) pulsatility are disrupted, thereby impairing reproductive function and leading to menstrual disturbance.[42] Like EA, menstrual disturbance is characterized by a spectrum of changes in menstrual function, ranging from amenorrhea, the most severe presentation (>90 days without a menstrual bleed), to oligomenorrhea (>35 but <90 days between menstrual bleeds).[42]

Bone Mineral Density

It is the combination of EA, neuroendocrine health, and nature of mechanical loading that determine the impact of exercise on bone health. Thus, under conditions of adequate EA, the bone health of athletes may be increased compared to sedentary controls due to the benefits of mechanical loading inherent to weight bearing exercise.[43] However, low EA can negate potential benefits of exercise on bone accrual and density.[43–45] It has been established that estrogen deficiency, inherent to both low EA and menstrual disturbance, is associated with low BMD in female athletes.[43–45] The neuroendocrine alterations that occur in response to low EA have deleterious effects on bone resorption and turnover, ultimately impacting bone density and fracture risk.[41,43] In the state of low EA, the body suppresses hormone production at the HPG axis, creating a state of hypogonadism, as a means of energy conservation for important and vital body functions. This adaptation to low EA and suppression of the HPG axis, disrupts the regular production of gonadal hormones, including gonadotrophin releasing hormone (GnRH), which disrupts pulse frequency and amplitude of luteinizing hormone (LH), further causing the ovaries to produce less estrogen and progesterone.

This cascade of hormonal disruption contributes to menstrual disturbance, and ultimately to the bone resorption and turnover that impacts bone density and fracture risk. Further,

hormones that have a strong positive correlation with fat mass are commonly disrupted in the state of low EA, including ghrelin, cortisol, insulin like growth factor 1(IGF-1), leptin, and Peptide YY (PYY). These same hormones are known to be associated with altered HPG function and adverse bone health outcomes.[43,46] Importantly, leptin is known to correlate with HPG function, such that low levels of leptin are known to be associated with disrupted LH secretion in female athletes with menstrual disturbance.[47] In animal models, increased PYY has been shown to attenuate GnRH secretion, and "stress-like" increases in cortisol have shown a similar effect.[48,49] All of these alterations are known to negatively impact bone formation and bone resorption markers, ultimately impacting BMD and fracture risk.[50] The Triad Consensus Statement characterizes bone health based upon BMD Z-scores, and includes the following categories: osteoporosis (defined as BMD Z-score of ≤ -2), low BMD (defined as BMD Z-score of -1 to -2), and optimal bone density (defined as BMD Z-score of > -1).[42] Bone health is of particular concern in adolescent and young adult athletes, because disturbances to bone accrual and formation is largely irreversible and has life-course implications on osteoporosis and injury risk.[51]

Endocrine

Low EA can result in endocrine alterations, which have been reported in female athletes as hormonal changes occur to conserve energy for vital bodily functions and processes.[52,53]. Particularly, endocrine abnormalities have been reported in female athletes with menstrual disturbance, including disruption of the HPG axis, altered thyroid function and appetite-regulating hormones, decreased insulin and IGF-1, increased growth hormone (GH) resistance, and elevations in cortisol. [25,29,54–56] The state of low EA with disruptions to endocrine function is posited to contribute to multiple physiological outcomes described by RED-S, yet more research

is needed to better understand the mechanisms and temporality of low EA, endocrine abnormalities and additional RED-S outcomes.

Metabolic

A decrease in resting metabolic rate (RMR) has been reported to be associated with low EA in female endurance athletes.[57] Further, one study showed that female athletes who were moderately energy deficient had a significant decrease in resting metabolic rate.[58]

Hematological

Low iron is common in female athletes, and this deficiency can contribute directly and indirectly to energy deficiency through impairments in appetite; thus, decreased metabolic fuel availability leading to impaired metabolic efficiency, leading to an increase in energy expenditure.[59] In one study, low EA was shown to be correlated with hematologic dysfunction, including low ferritin and iron deficiency anemia, in adolescent and young adult female athletes.[60]

Growth and Development

Significant low EA, such as severe anorexia nervosa, has been shown to be associated with impairments in growth and development.[61–63] Additionally, anorexia is shown to impair hormones that are associated with growth, including IGF-1 and GH.[64] Studies among athletes with amenorrhea have shown impaired GH secretory patterns, decreased GH and IGF-1 secretory response to exercise accompanied by increased GH levels, and decreased IGF-1/ insulin-like growth factor-binding protein 1 (IGFBP-1) ratios.[65] More research is needed to demonstrate the effect of low EA on growth and development in athletes in less severe energy restricted states.[65,66]

Cardiovascular

Some research has shown impaired cardiovascular health, including early atherosclerosis, endothelial dysfunction and unfavorable lipid profiles, in female athletes with amenorrhea, including lower heart rates and systolic blood pressure compared to athletes with regular menses;[67–69] however, improvements in vascular endothelial function were seen with the resumption of menstrual periods.[70] Severe low EA, in a non-athlete population with anorexia, was shown to be associated with severe cardiovascular concerns, including valve abnormalities, pericardial effusion, severe bradycardia, hypotension, and arrhythmias.[71]

Gastrointestinal

Gastrointestinal (GI) function, like bloating and constipation, has been reported to be negatively correlated with low EA in a population of elite female Swedish and Danish athletes, as well as a clinic sample of adolescent American athletes.[60,72]

Immunological

It is hypothesized that the immune system is negatively impacted by the state of low EA. Findings from a study of 21 Japanese elite, collegiate runners reported more upper respiratory symptoms and lower immunoglobulin A secretion rates in the athletes with amenorrhea versus eumenorrheic athletes.[73] Low EA was associated with increased likelihood of illnesses in an observational study of elite Australian athletes before the 2016 Rio Olympic Games.[74,75] Additionally, using amenorrhea as a surrogate marker of low EA, a study of Japanese collegiate runners reported that those with amenorrhea (n=21) had increased likelihood of illnesses, as compared to eumenorrheic athletes.[73]

Psychological

The temporal relationship between psychological concerns and low EA can be challenging to identify, such that psychological concerns and low EA are often observed in tandem and reinforce the other.[21] Low EA in athletes has been reported to be negatively associated with psychological well-being, such as depressive traits, psychosomatic disorders, disordered body image, and a decreased ability to manage stress.[23,76,77] Psychological concerns have been reported to increase with increasing severity of low EA; women with anorexia report the most severe psychological concerns, compared to women with amenorrhea with more mild energy restriction.[76]

Epidemiology of the Triad and RED-S

Reports on the epidemiology of the Triad vary markedly, due to large inconsistencies in measuring and defining low EA, menstrual disturbance, and low BMD; the epidemiology of the full set of RED-S physical health outcomes is widely unknown. Additionally, existing studies are heterogeneous with respect to sample size, participant age, sport type, and competitive level. A longitudinal study of non-collegiate elite adult female athletes (n=40), 18–38 years of age (mean age = 26.3 ± 5.7), reported that up to 62% had low EA or reduced EA, 60% had menstrual disturbance, and 45% had low BMD, based on self-reported data.[57] A 2018 clinic based population of athletes ages 15-30 years (n= 1,000) reported that 47% of athletes had low EA, and that women with low EA had significantly increased odds of menstrual disturbance (odds ratio (OR)=1.92) and impaired BMD (OR=1.72).[60]

The epidemiology of the Triad and RED-S across the population of collegiate female athletes is not well understood, given organizational limitations on accessing this population for research purposes, and other biases towards male-centered sports science research and prioritizing male sport outcomes. However, a recent longitudinal study of female collegiate

athletes at Stanford University (n= 323) found that 27% of women reported having oligomenorrhea or amenorrhea.[78] Further, while only 6% met criteria for low BMD, 16% had a history of at least one stress fracture or bone stress reaction, and the burden stress fractures was as high as 34% among Cross Country runners.[78] This finding suggests that distance runners face factors beyond low BMD that place them at risk of bone injury. This study limited its definition of low EA to self-reported current/past history of disordered eating or clinically diagnosed eating disorders; therefore, this measure captured only 7 reported cases and likely greatly underestimates low EA in this sample.[78]

Distance Runners at High Risk of RED-S Outcomes

Much of the foundational literature on menstrual disturbance and low BMD in female athletes focused on female ballet dancers [12,79–84], as well as endurance sport athletes, like distance runners [11,85–88]. These studies reported an increased risk for low BMD and increased bone injury risk in these athlete populations. Female distance runners continue to experience high risk of the Triad, due to the significant volume of training required by the sport, in addition to bodyweight pressures that encourage low body weight for increased performance [89]. Studies on female distance runners, specifically, have reported a disordered eating prevalence of 33% and a prevalence of severe menstrual disturbance as high as 36-69%.[44,90] Additionally, elite collegiate runners are reported to experience bone stress injuries at a rate exceeding 20% per year.[91]

Known Risk Factors for the Triad and RED-S

To date, research on the Triad has focused largely on individual-level behavioral characteristics, as well as biological or physiological characteristics identified in lab studies with small samples of female athletes.[47,92–94] Due to this focus on individual-level behaviors and

physiology, structural level factors, such as access to resources for mental and physical health and the influence of coaches, have received little attention from a research or prevention and intervention standpoint.[95] Of the few population level studies that have assessed non-physiological or psychological risk factors for low EA and Triad outcomes.[38,60,89,96] Similarly, studies investigating non-physiological risk factors focus largely on health and performance risk factors, such as decreased endurance and muscle strength, and do not account for structural variables such as coaching influence or the team and academic environment.[21] Included in the Triad consensus statement is a reference to just two studies that investigate inappropriate coaching behavior as an upstream factor for the Triad.[97,98] To date, no studies have undertaken a true structural analysis of risk factors for the Triad. The influence and impact of collegiate coaches on athlete health and wellbeing is largely understudied and necessitates future research.

Risk Factors in the Sport Environment

The primary structural level risk factors relevant for collegiate athletes with respect to the risk of RED-S include the coaching and team environment, as well as media and societal influence. The sport environment poses unique risk to female athletes.[89] Athletes face high pressures to excel in both school and sport. Team leadership, including captains and coaches, play a vital role in shaping the team culture and environment related to eating and exercise behaviors.[97,99] Body weight and food-related comments from coaches significantly contribute to a harmful team environments and such comments were reported to be incredibly consequential on an athlete's eating and exercise behaviors.[97–99]

The 2016 *International Olympic Committee (IOC) consensus statement: Harassment and abuse (non-accidental violence) in sport* identified the coach and athlete power differential as a context that enables such harassment and abuse.[100]. Coaches are advised against pressuring

athletes to lose weight or supporting harmful weight loss behaviors.[100] Additionally, it is best practice for coaches to refer athletes to speak with nutritionists if an athlete expresses interest in losing weight.[98] This IOC consensus statement recognized the environmental and structural factors that negatively impact athlete health and wellbeing, where the coach/athlete power differential is highlighted as a particular context that enables such harassment and abuse.[100] This IOC statement calls for urgent policy initiatives that illuminate clear mechanisms of action to prevent *non-accidental violence* of athletes, calling on stakeholders in sport to implement and monitor "safe sport, "or an "athletic environment that is respectful, equitable and free from all forms of non-accidental violence to athletes".[100] Importantly, this consensus statement suggests that safe sport is a basic right of every athlete. Notably, the IOC statement does not suggest appropriate consequences for perpetrators of athlete harassment and abuse, or address concerns of retaliation for athletes who report these acts. This is a great concern, as demonstrated by the case of Mary Cain.[101]

Another component of the sport environment that poses risk to athletes is the broader, cultural context around body image and dietary norms. Research suggests that the prevalence of disordered eating is higher among "lean" sport athletes, or sports that emphasize a lean physique and/or a low body weight, such as running, swimming, and gymnastics.[102] In a sample of national team level athletes, the prevalence of clinical eating disorders was greater among athletes in leanness sports (46.7%) as compared to athletes in non-leanness sports (19.8%) and controls (21.4%).[99] It is suggested that leanness sports, like distance running, may have "unwritten rules" for low bodyweight, and the pressure to achieve the "ideal body weight" whether real or perceived, and can lead to disordered eating behaviors.[103,104] Athletes themselves may misunderstand the risk associated with their own adherence to rigid eating and exercise

behaviors, given a sport culture that conflates these behaviors with discipline and dedication. A qualitative study found that athletes may fail to recognize their own eating disorder and disordered eating behaviors, because low body fat levels are "often required for participation" in elite sports and lead an athlete to believe that these behaviors are acceptable or even "normal".[105] Further, female athletes with a muscular body types that do not fit the sociocultural ideal body shape characterized by thinness may behave in ways to try to change their body composition through dieting to meet these societal ideals, even if muscularity is beneficial for performance in their sport.[98]

The media, diet, and beauty industries provide prime examples of the societal messages that frequently crossover into the sport environment. These industries continue to profit off of cultural messages that promote weight loss and unhealthy practices to achieve societal ideals of "attractiveness". [106–108] Messages from the media have been shown to play a strong negative influence on young athletes, particularly messages emphasizing the thin ideal.[108] Issues arise when a young woman "cognitively buys into socially defined ideals of attractiveness" and engages in behaviors to try and meet these ideals.[108] These structural level forces are important to uncover, in order identify upstream factors for intervention in future public health efforts, given that athletes do not exist in the microcosm of sport and are subject to these influences.

Theoretical Framework

In both historical and modern society, patriarchal and capitalist tactics have profited off of cultural messages rooted in the submissiveness of women and promotion of thinness as a moral imperative and marker of success.[106,107] Risk for low EA, with or without DE, can be examined through feminist theory.[109,110] Female athletes are not immune to structural- and

cultural-level messages that promote the thinness ideal and objectification of the female body.[111,112] According to objectification theory, women and girls are subject to significant body monitoring, shame, anxiety, disordered eating, depression, and sexual dysfunction, due to constantly worrying about external perceptions of beauty of body image.[113] Further, women are taught that they are in control of their appearance and can act accordingly to achieve this thinness ideal, which reinforces discorded eating behaviors.[114]

Interestingly, sport is one area where traditional gender body image and body aptitude expectations are not applicable. Gendered etiology of body image enforces that male bodies are "capable, strong, and powerful," while a woman's bodies are portrayed as "sexual" objects to be appreciated by men; in sport, female athletes embody both the feminine and the masculine.[113] However, pressures of the thinness-ideal of society may be heightened among elite female athletes, as they often embody perfectionist attitudes that extend to their physical bodies.[98] As previously established, the pursuit of thinness and weight loss is associated with adverse health outcomes, both short and long term.[21] The sport environment can further compound health risks for female athletes, when the pursuit of thinness is combined with the pursuit of strength and performance, as it represents physiologically opposing demands.

Structural influences, such as media portrayal of idealistic body images and team and coaching pressures to perform, work in concert to promote and sustain the physiologic state of low EA that harms the health of female athletes. When women suffer the health and performance consequences of low EA, male athletes maintain their standing as physically and mentally superior. Despite established evidence of the adverse effects of low EA, menstrual disturbance, and low BMD, these syndromes are often ignored and written off as a "normal" part of the female sport experience. Until structural forces that encourage, promote, and sustain low EA are

addressed, and the health of female athletes is prioritized, these women will continue to suffer the downstream health consequences of existing in a patriarchal system.

Over 30,000 women compete annually in NCAA distance running, including 14% of whom participate in Cross Country and/or track and field. While the Triad is not unique to collegiate runners, this high-risk population is well-defined and contained within the regulated body of the NCAA, making them a population with significant potential for early prevention and intervention. Thus, knowledge gathered in this population may be translated towards the creation of prevention and intervention frameworks for future generations of female athletes. Given the established health risk of this group and significant potential for intervention, NCAA collegiate female distance runners are the population of focus in this dissertation. This dissertation will: (1) highlight the lived experiences of current and former NCAA Division One (DI) female distance runners' perceptions of body image and disordered eating, as well as coaches' influence on health and wellbeing (2) to understand how the ten RED-S health consequences cluster together in this population of runners (3) understand the burden of bone injury, with respect to RED-S consequences.

Specific Aims

Aim 1: To describe current and former NCAA Division One (DI) female distance runners' experiences of perceived norms of body image and disordered eating in their sport, as well as the emergence and influence of coach-athlete power dynamics.

Aim 2: To analyze and describe how RED-S health consequences cluster in this population of National Collegiate Athletic Association (NCAA) Division One (DI) Cross Country Runners.

Sub Aim #2a: To identify and describe demographic, personal, disordered eating and emotional health variables that predict the class of RED-S consequences an athlete experience.

Aim 3: To analyze how latent class membership predicts bone injury outcomes, including both subtle and severe bone injury outcomes (stress fractures).

Hypothesis: Women assigned to latent classes characterized by high menstrual disturbance will have the greatest prevalence of bone injury.

Figure 1.1. Female Athlete Triad (Triad) Framework

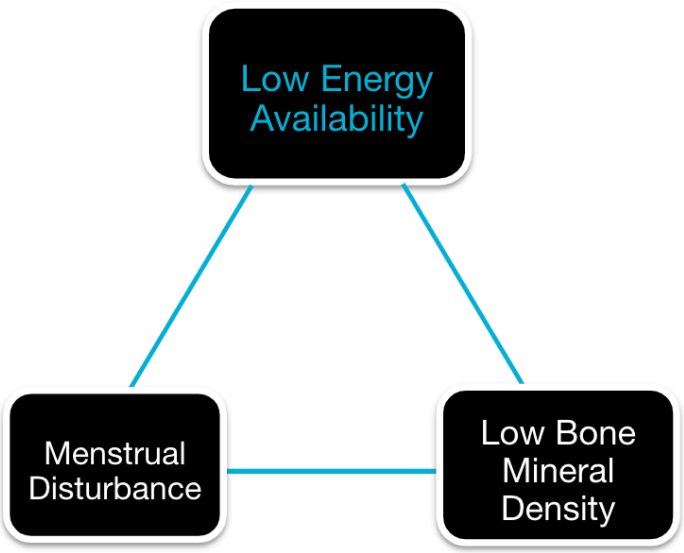
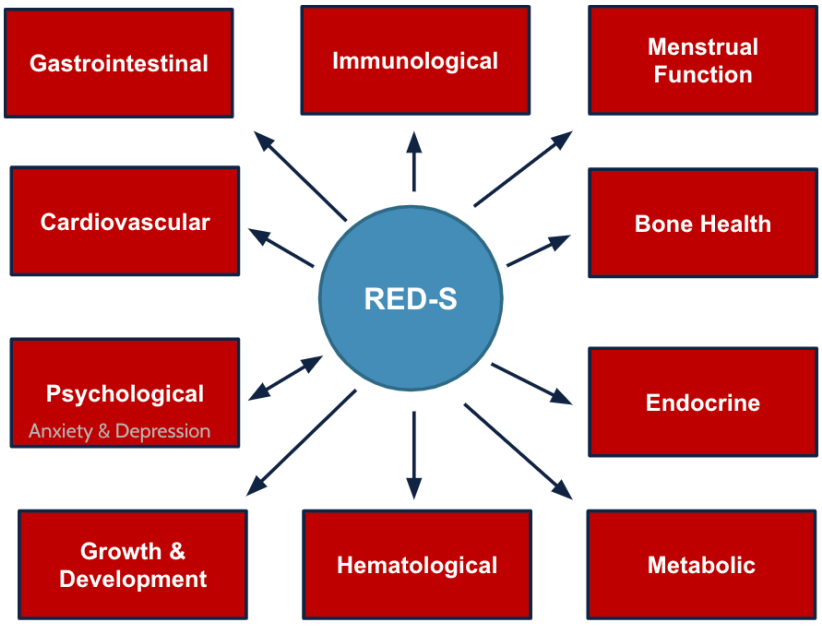


Figure 1.2. Relative Energy Deficiency in Sport (RED-S) Framework



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Chapter 2

Cultural and Environmental Associations with Body Image, Diet, and Wellbeing in NCAA DI Female Distance Runners: A Qualitative Analysis

Abstract

Objective: The purpose of this study was to describe current and former NCAA Division One (DI) female distance runners' experiences of perceived norms of body image and disordered eating in their sport, as well as the emergence and influence of coach-athlete power dynamics.

Methods: The study sample included 29 current and former female NCAA DI female distance runners, defined as competing in 800-meter distance or greater. Interviews were conducted, audio-recorded, and hand transcribed. A thematic analysis was performed and presented.

Results: Two major themes emerged: 1) sport body ideals and body image norms and myths that persist in the sport, and 2) the power dynamic between coach and athletes. It is not clear whether sport body ideals and culture of running influences coaching culture, or if the coaches, who maintain positions of power in the sport, perpetuate the culture. These themes likely feed into each other and reinforce the existing and dominant mentalities of the sport.

Conclusion: Findings revealed that sport body-image ideals and the power dynamic between coach and athlete may contribute to female athlete's risk of disordered eating and body image disturbance, resulting in adverse health consequences. A significant opportunity presents for the NCAA and athletic departments to develop and implement prevention and intervention programs to prevent.

Introduction

Over 15,000 women compete in National Collegiate Athletic Association (NCAA) Cross Country, with about 6,000 competing at the Division One (DI) level.[1] The culture of corruption and maltreatment in elite female running has recently gained national media attention. Nike's running program received coverage about Mary Cain's personal account of the maltreatment she endured under her head coach Alberto Salazar. [2] The driving theme of this press coverage, featuring Cain and her Nike teammates, has been harmful coaching, particularly as it applies to unhealthy bodyweight expectations and pressures to be thin. Since Cain's story was published, many female runners have shared their personal stories, about the negative physical and psychological consequences they faced as a result of pressure to obtain a particular ideal "runner body" type, on social media outlets like Twitter and Instagram.

Research on the health status of female runners has been of interest since the 1970's, following the significant rise in female sport participation following the 1972 introduction of Title IX [3]. Studies have shown that female distance runners experience a high risk of relative energy deficiency, or insufficient calorie intake to meet the demands of energy expenditure, with or without disordered eating.[4–8] Female distance runners continue to experience high risk of relative energy deficiency, due to the significant training volume required by the sport, in addition to bodyweight pressures that encourage low body weight, under the assumption that it improves performance.[9] While disordered eating is not the prerequisite for relative energy deficiency, the prevalence of disordered eating among female runners has been reported to be twice as high as their non-athlete peers, ranging from 33% to 50% versus 8% to 17%, respectively.[10–12] Further, it is important to understand factors that contribute to disordered eating

in this population, because the disordered eating is associated with psychological comorbidities, such as anxiety, that significantly impact wellbeing.[13] The epidemiology of Relative Energy Deficiency in Sport (RED-S), a framework to consider the health and performance effects of relative energy deficiency, is not well understood across the population of collegiate female distance runners, as well as general sport populations, in part due to organizational limitations on accessing this population for research purposes. The current study was motivated by an interest to understand the culture of NCAA distance running and to identify structural factors that impact athlete health. The intent was to inform two significant gaps in the literature: (1) the limited qualitative work capturing the lived experience of this population, and (2) a structural analysis of influences female runners face with respect to body image, diet, and physical and psychological health.

The purpose of this study was to identify factors that contributed to the onset of disordered eating and body image disturbance in a population of current and former NCAA Division One (DI) female distance runners and to investigate the resulting psychological and physical health consequences of these women. A prime study objective was to examine the nuanced cultural and environmental messages that perpetuate and sustain disordered eating and body image disturbance in the distance running community.

Methods

Subjects

Study Sample

The study sample included 29 current and former female NCAA DI female distance runners, defined as competing in 800-meter distance or greater. To be included in the study,

participants had to be 18 years of age or older, participate in at least one full season of Cross Country or track and field at a DI institution. All participated screened in at risk of an eating disorder and/or the Female Athlete Triad. Runners currently undergoing in-patient treatment for an eating disorder and/or other psychological disorders and runners not fluent in English based on self-reported data were excluded from the study. Identification numbers are used in the results section to protect anonymity and identify block quotes and exact phrases by participants. This study was approved by the University of Michigan Institutional Review Board.

Procedure

Recruitment

Study recruitment took place between May and December of 2018. Recruitment materials were shared on social media platforms (i.e., Twitter, Facebook, and Instagram), sent to coaches and retired collegiate athletes participating in Midwest running clubs, and sent though a listserv of former student-athletes from a large Midwestern university. Interested individuals emailed the study team directly, and those who gave consent were screened for eligibility using a modified version of the LEAF-Q (the question on birth control use was eliminated) FAST questionnaires to screen for risk of relative energy deficiency and disordered eating, respectively.[14,15] To be included, participants had to have a modified LEAF-Q scores ≥ 7 and/or FAST scores ≥ 79 (i.e., subclinical to clinical disordered eating).

Protocol for Follow-Up

Individuals who completed the screening survey and were deemed eligible were contacted within one week, inviting them for a study interview. Those who did not meet

eligibility requirements were sent an email notifying them of ineligibility and thanking them for their interest. If an eligible participant did not respond to the interview invitation within one week, follow-up emails at one-week and two-weeks after the initial invitation email were sent. Interviews were completed in-person or by Health Insurance Portability and Accountability Act (HIPPA) compliant video conferencing.

Development of Interview Guide

Questions asked in semi-structured interviews were based on a review of the literature and focused on the lived experience of each athlete and on their mental and physical health. Topics of particular initial importance included body image, eating behaviors, nutrition, menstrual and reproductive health, injury history, and help-seeking behaviors (Table 2.1). In preparation for the interviews, questions were reviewed and edited by several current and former student-athletes, and revisions were made based on feedback. The final version of the interview guide resulted in an interview that lasted approximately 45 to 60 minutes.

Interview

In-person interviews were conducted in private locations selected by the participant or via HIPPA-compliant video conferencing. All interviews were audio-recorded using a handheld recording device. Participants were debriefed following the interview and provided resources for local and national psychosocial support services, given the sensitive nature of the research questions.

Analysis

Addressing social positions

It is important to acknowledge the researchers' theoretical position and values in relation to the particular context of this qualitative study.[16,17] The principal investigator (PI) conducted all of the interviews and had lived experience as a varsity-level DI student-athlete in the sport of rowing. She also experienced the Triad, RED-S and was diagnosed with an eating disorder during college and considers herself in active recovery. She completed all the interviews and disclosed her status as a former DI student-athlete with a majority of the interview participants and shared her history of the Triad with participants if prompted by the interviewees as a way of making them feel comfortable and building rapport.

Thematic Analysis and Codebook Development

All interviews were audio-recorded, and hand transcribed by two research assistants. We used thematic analysis as a theoretically flexible method to organize, describe, and interpret the data [17]. The first step involved becoming closely familiar with the data by reading and re-reading the interview transcripts.[17] An initial codebook was created in tandem with the interview guide, based on the existing literature and the experience of the research team.

Codebook and Coding Discrepancies

Following completion of the interviews, the codebook was iteratively revised as the coding process ensued. A sample of 10 transcripts was coded using the original codebook, and new codes were added based on emerging themes. The final codebook was solidified after double coding those same 10 transcripts with the updated codebook, and coding discrepancies were addressed. Final codes were entered into Nvivo 8.

Results

Sample

The sample for the current study included 29 current and former NCAA DI female distance runners. Participants had a mean age of 24.6 years (range: 18-36) and represented 19 universities across the nation. The mean LEAF-Q score was 12.8, and the mean FAST score was 74.4 (Table 2.2). The study sample did not differ in mean age from the total eligible sample of women (n=63) but did have greater average LEAF-Q and FAST scores (11.9 and 72.1, respectively), given inclusion criteria.

Themes

Two primary themes with subthemes emerged from the data: 1) sport body ideals and body image norms and myths that persist in the sport, and 2) the power dynamic between coach and athlete, as it pertains to body and performance ideals and expectations.

Theme 1: Sport Body Ideals

Women felt the sport of Cross Country and long-distance running had a deep and unspoken culture that supports the pursuit of thinness and pushing the body to extreme, unhealthy limits. Women spoke about a culture that encourages restrictive eating and training that exceeded "healthy," in pursuit of the perfect "runner body" image and sport performance. Women noted cultural cues that reinforced harmful eating and exercise behaviors in their sport environment that were precursors, or risk factors, for their own experiences; however, many women dismissed such behaviors as "normal" and "expected". We identified three sub-themes within the sport body ideals theme: the *ideal "runner body*," the sport mentality that promotes the "*lighter is faster*" mentality, and lastly, the *event-type body identity*.

Ideal "Runner Body"

Cultural norms and cues about body image and performance were mentioned as significant triggers for restrictive eating and body image disturbance. Many women were quick to state that they didn't "look like other runners" and described physical attributes about their bodies that made them believe this to be true. One participant explained, "I definitely didn't fit that like typical Cross Country body image, which is usually like longer, elongated, longer legs, very skinny" (ID 3). Another woman described that she did not have the "chiseled" (ID 66) "look" of other runners.

Women spoke about the elusive "runner-body" type, characterized by "skinny legs and smaller thighs, but that are muscular and skinny… 6 pack type abs, flat abs and that is what people kind of imagine" (ID 41). Women's relationship with their physical bodies was both mentally and emotionally complex. As elite distance runners, these women felt that their physical bodies represented dedication to the sport through an achievement of the "ideal" physical aesthetic. As one woman described, "you see certain body types as being portrayed as more successful" (ID 13). In a similar way, these women appeared to think that their physical bodies communicated their success in this sport to the world; if they could achieve the "ideal body" then they were worthy of respect and accolades in the sport. Further, one participant talked about how the distance body ideal continues to be perpetuated due to a perceived correlation between body size and sport success, citing "women who are tiny and carry nothing extra and running top of their game" (ID 36), as an example of the type of runner body that is perceived as a "success." It was a common belief that women who were "tiny" (ID 36) and "who have long skinny legs" (ID 41) were the ones that embodied the successful and idealistic female distance runner and had the body type that allowed for success in the sport.

Participants noted a complex and competing interest between body size and health and performance. Interestingly, one woman commented on the fine distinction between "looking healthy" but thin, compared to looking "skinny" (ID 18). This participant explained the following about her competitor's weight loss, "I remember actually saying 'oh, they are skinny now' and looked upon as she has a really big problem if she lost too much weight, but if it was not too much and she still looked healthy then it was praised" (ID 18). This fine line between "looking healthy" and looking "skinny" was not made clear in the interviews.

This "runner-body" archetype had many overlapping features with the cultural "thin ideal," that emphasizes thinness, with the addition of lean muscle [18,19]. Despite this distinction from the cultural body ideal, female athletes were not immune to structural and cultural-level messages that promoted thinness. Pressures to meet the cultural thin-ideal may have played a small, but notable, role in the pursuit of the "runner-body" type. So, while these women primarily mentioned the pressure to meet the described athlete aesthetic, the following woman shared an insightful connection between the duality of sport and societal body standards that women face:

> "I definitely think that the culture of distance running encourages some disordered eating patterns. So, I wouldn't be surprised if more women have some type of disordered eating behaviors than is typical. But at the same time, I feel like being a woman in this society is hard, so I feel like every woman may have struggled a bit more than we think." (ID 22)

Many women expressed that the culture and environment of long-distance running contributed to their desire to achieve a perfect "runner body" and control food and exercise. Women shared how factors in the running environment influenced their desire to control body weight and food intake, dating back to childhood and their current lives. It was clear that female distance runners received messages from coaches and family members that they would be better, or more successful, runners if they were in a smaller body.

"Lighter is Faster" Mentality

A deeper theme entangled with the notion of the ideal "runner body" is the false belief that lower body weight positively correlates with improved sport performance. This idea is represented in the mantra "lighter is faster" and reinforces the runner "body ideal," a common phrase regularly accepted as a truth in the running community and mentioned by the women.

Interestingly, the idea that "lighter is faster" appeared to develop early in women's lives, at a time that intersected with puberty and the time of natural body weight and shape changes. This topic brought up discomfort and feelings of fear around that period of physical development, which often coincided with their adolescent weight gain. As one woman shared, "A lot of people have personal experience with that (i.e., belief that lighter is faster); a lot of girls who are 11 or 12 are really fast, and you think you are going to get faster and you don't" (ID 53). One woman described her personal take on running performance and weight gain during puberty:

> "I felt like it was too early … that it reinforced a belief or idea that being that pre-pubescent state made you fast. It seemed with a lot of those girls, once they grew into their bodies, or once they actually went through puberty, they weren't as fast, and I felt like that was even detrimental to my view on how things should be" (ID 41)

Asking about this "lighter is faster" mentality generated a defensive reaction in some participants, and many called upon the physics of running and rationalized this phrase by citing the inverse of the mantra, that higher body weight correlated with slowness. Others understood the limitations of the "lighter is faster" mentality and the potential harms of believing that to be true at any cost, or as one woman noted "it's only true to a point" (ID 47). Further, many women realized that this idea was short-sighted, having witnessed the subsequent downfall in performance related to long-term under-eating and over exercise. One woman shared, "…you lose weight and start running better for a while, until you break. Until something breaks down

physically or your body no longer has enough energy" (ID 37). Another participant said, "… it is such a short-lived time that that makes you faster" (ID 30).

Many participants were aware of the harm that this mentality could cause and witnessed the downfall of pursuing weight loss for improved performance, either personally or from a teammate or competitor. One woman described how the "lighter is faster" mentality could be harnessed as a "healthy" performance mechanism for some women, but taken to an unhealthy extreme for women with predisposition to disordered eating and control seeking behaviors:

> "Some women do need to lose weight to run a little bit better, and it's just true. And they could be, they can approach it in a healthy way. Like I felt like I weighed less during the season, but it wasn't a weight that I felt was sustainable for an entire year. I would've never wanted to be at my weight for 12 months out of the year. And I knew that versus women I've interacted with that have had eating disorders where it's very much like control over food. I don't know, it's a hard thing when it comes to it. It's about something deeper." (ID 35)

The majority of the participants felt that they did not embody this "runner body" and had failed to reach full performance potential because they could not achieve this aesthetic. However, if no one embodied this sport ideal, it begs the question of how useful this ideal remains and why women strive for this body type, when it is the exception not the norm. Further, it was clear that "lighter is faster" was learned early in women's running careers and continued to be a pervasive belief throughout their running careers.

Event-Type Body Identity

Many women commented on the difference in body ideals and eating behavior and mentality by event group. The differences between event groups were defined by race distances that often required different training and dietary energy demands and may impact body weight and shape. Middle-distance events include 800 meter and 1600-meter events while long distance events include the Cross Country races of 5, 8 and 10 kilometers. Importantly, a majority of

woman who compete in middle-distance events as their primary event will also compete in Cross Country events, and vice versa.

One participant explained that there is a "… huge body shift too from Cross Country to track. Like where the muscle is and what type of workouts you're doing. Definitely changes body type a bit" (ID 10). The "middle-distance" body-type appeared to embody greater muscularity and physical strength. One participant commented that "… 800 (meter) runners are usually a little bit taller a little bit more built like more muscle. Versus like you think of a Cross Country runner being like 5' 2" and very, very lean muscle, more slow twitch." (ID 10)

Beyond body image ideals, middle-distance runners appeared to have a healthier, or more positive, mentality around food intake and muscularity, compared to the thinner-body ideal consistent with the longer distance runners. One participant explained the mentality she experienced in her middle-distance group:

> "You (middle-distance group) talk about being stronger versus being tinier. Then it also breeds a different type of mentality is slightly drawn to it, so breeds a little healthier attitude around food…who you are aspiring to look like and then the words you use to describe an 800 runner versus more of a distance runner." (ID 37)

Another woman shared that having physically strong middle-distance female role models that "… carry more muscle and have a different body type" (ID 37) was beneficial to her own body image, "… you are aspiring to run like these girls and women … so your idol looks different, which helps tremendously" (ID 37).

Additionally, there appeared to be a strong in-group body-image identity within the middle and long-distance event groups, yet this caused conflict for women competing in both middle- and long-distance events, and in both track and cross county seasons. As the event season shifted, women felt pressure to shift their body size. This change from middle to longer distance events, or shift from track to Cross Country season, brought up body image challenges

for women that naturally fit into the "middle-distance" body-type, as they entered into the long distance-running event season. One participant, that identified as both a middle- and long-distance runner, shared that she has been told she was "too big to be a Cross Country runner" and "way too big" (ID 10) to race the 1600-meter event. Another woman shared her experience as both a middle and long-distance runner:

> "Running Cross Country when you're mainly a middle-distance runner you're definitely not one of the stick thin like smallest girls on the team. So, it is a little bit different to toe the line with another girl next to you that you feel like you could just swallow whole. Yeah, but it's just, the stigma was there. You could feel it. It was in the atmosphere for sure." (ID 50)

Some women shared that they were commonly assumed to be in the sprinting event group because of their physical build. "I definitely most of the time get the comment of '… oh are you a sprinter because I have like very stout legs, like muscular legs, muscular calves" (ID 3), another lamented that, "I think I was just always aware or made aware that when people looked at me I looked more like a sprinter in some way, which is a weird, I think a weird thing to say to a person" (ID 2).

Women had a particular event-based body image ideal, within the broader "runner body" ideal, and it appeared that these women wanted their physical appearance to act as a signal of their membership in a designated group. Their membership in a specific group and event type reflected something much deeper and personal that spoke to their character and values as a person, placing additional pressure on their physical appearance. While the majority of current and recently graduated college distance athletes did not feel that the sport aesthetic had truly shifted to accept a more muscular body type overall, it is possible that the body ideals of middle-distance runners pushed the trend in a direction that valued strength and health over thinness.

Specific to running culture, women shared that "unhealthy" (ID 43) eating and exercise behaviors and attitudes continue to persist, because the sport culture prioritizes performance and success over the health and wellbeing of athletes. One athlete talked about how the discipline required by the sport of distance running, combined with the temperament of its athletes, "… lends itself to disordered eating" (ID 35). The belief persists that the intense physical exertion required by the sport of distance running and the associated competitive pressures to perform reinforce weight loss as a way to gain a competitive edge. This mentality has become the norm in the sport, despite the risk of engaging in unhealthy means to strive for these standards. As one woman describes:

> "I think part of it is that in a lot of these sports it is seen as how much you can push yourself as a factor. I think that it manifests itself in so many ways, you know making sure you do all your workouts and lifting…I think that it goes far, the source for me was pushing over the edge, because I wanted to be better. You are offered a lot of ways to improve, and you're always trying to prove it and taking that desire to be faster or be a better athlete and go more to an extreme." (ID 8)

Another woman shared that she was able to "… get away with" disordered eating, because it was easily "… disguised by training" and performance goals (ID 47). This pursuit of excellence in sport is the expected mentality, and the intensity at which athletes' function in sport and in their personal lives is normalized and justified as dedication to the sport and to their overall success.

Theme 2: The coach-athlete relationship and power dynamic

Women described the differences in their relationships with high school and college coaches. The common theme was that women revered their high school coaches and maintained relationships with high school coaches as mentors and friends. However, participants described

their collegiate coaching relationships in a much more serious tone, revealing the intensity and "business-like" environment of NCAA DI athletics. We identified three sub-themes, *Recognition, Coaches Control*, and *Body and Food Comments*.

Recognition

Women talked about looking for attention from their college coaches and seeking recognition for their hard work. One woman described how she and her teammates approached this relationship, "… we want to make her [the coach] happy, you were an athlete you know it doesn't matter if you like her…You have that drive for her satisfaction and make her happy" (ID 9). Another woman explained this coach-athlete dynamic:

> "We just wanted him to validate us. Each of us really worked hard for him. And, so I think it was kind of rejection, and I just want him to recognize that I want this and I'm working really hard. So, it was self-hatred in the like oh I've disappointed him and someone else hasn't disappointed him. (ID 1)"

It was clear that athletes had a strong desire to gain praise and validation from college coaches, and receiving this praise was closely tied to athletes' sense of success and self-worth.

Coaches Control

Concurrent with the need for validation and attention from coaches, it was clear that many collegiate coaches were using this dynamic to their advantage in a way that contributed to psychological harm and distress on the team. As described in the sport body ideals, the mentality of pursuing excellence at any cost was not limited to the individual athletes, but it was also seen in the behavior of coaches. One athlete described how it was common for a coach to prioritize team performance outcomes over the health of individual athletes, and this played out in situations where coaches knowingly allowed athletes struggling with disordered eating to continue competing, despite the harm it may have caused that woman:

> "Yeah, there is definitely an unhealthy thread through the running community in general… It is kind of known, I don't know how true it is or not, that some teams have worse issues with the eating disorders than others, depends who the coach is, if they are running fine, they let it happen ….I am more bothered by people who are in positions of power that see it and let it happen and don't care about the health of the athlete, because they are competing well." (ID 43)

Women were in a position of knowing that their running career was in the hands of the person causing them distress and that power dynamic was made evident throughout the interviews. Several women commented on the team culture that coaches created; one women described it as a culture of "… fear or pressure to perform very well very quickly" (ID 2), explaining that, "if you were doing really well you got a lot of positive feedback, you were really elevated and given a lot of attention; and when you weren't, you were treated as if you weren't trying hard enough … being in that environment makes you feel a little crazy" (ID 2). Another woman echoed this, saying "they [coaches] still didn't think that I was enough, like they still felt I wasn't disciplined and still felt that I didn't care enough" (ID 18). Another woman added that "… his [the coach's] relationship with everyone was distant, I felt like everyone was trying to win his approval, it was really hard to ever win his approval. That is kind of how it was with him" (ID 30).

Other women commented that coaches withheld communication and feedback on performances as a form of punishment when the team "wouldn't perform" (ID 6) to the coaches' expectations. One woman shared:

> "She [the coach] would get upset and like, she would not talk to us after the races, or she would walk away or something like that. And like then later on would kind of talk about what happened. But she would like, first impressions after the race, she would not be that great at handling it. And then if people were struggling I feel like they would try and go talk to her and feel like they didn't get much back." (ID 6)

Regarding coaches' treatment of athletes, one participant said, "… they treat them like cattle" (ID 49), and another said that coaches "… never made an effort to get to know their athletes in any way" and felt her and her teammates were "… just a means to their end" (ID 30). Another woman commented that she has "gasped" (ID 49) at some of the stories that her runner friends have told her about the way the coaches treated the athletes. Sadly, one woman shared that she was "so relieved" when she graduated and removed herself from her college team, because she lost her love of the sport, due to her coaches. This woman stated, "… I couldn't deal with her [coach] anymore or the pressure. It went from something I loved to do, to something I couldn't even deal with. That was the worst thing" (ID 9).

Athletes described how significantly their coaches impacted their mental health and wellbeing, leading some women to leave their teams and the sport entirely. It is clear that some coaches created a communication barrier with athletes as a way to influence athlete behavior and maintain power and influence.

Body and Food Comments

In this coach-athlete relationship, bodyweight and shape pressures were a driving narrative. Body weight comments, plus the overarching feelings of never being good enough to achieve approval of the coaches, contributed to women's feeling of resentment towards coaches and greatly contributed to overall distress and feelings of anxiety around their coach. One athlete even said that, upon reflection, she probably would not have gone to her university because of body comments she heard her coaches say to teammates (ID 11). Athletes shared stories that they heard of competitors on other teams sharing stories of "… really awful stuff," like one example of a coach saying, "… if you jump up in the mirror you shouldn't see anything moving" (ID 53). One athlete described the harmful environment created by the coaching staff on her college team:

> "The coaches there are really into, put a big emphasis on weight, especially the women; I don't know why. Reinforcement of — if you were smaller you will be faster, it was pounded into us from day 1, and a lot of the girls on my team experienced disordered eating patterns." (ID 30)

Another athlete shared her coaches' expectations for teammates body weight and size: "She had all the girls sat down and told us we had a weight issue on our team, and we all needed to push to be below 14% body fat … it was not healthy at all" (ID 43). One woman felt that she was able to avoid her coach's criticism at the interpersonal level, because she was "small enough," and, because of this, she was "never the brunt of her [coach's] wrath in terms of body size" (ID 9). Other women were not so lucky, and one woman shared:

> "The head coach specifically would sit us down and tell us stuff, like he sat me down before winter break and was like I am afraid you are going to gain weight over Christmas… He would do that with everybody." (ID 30)

This same athlete added that her assistant coach added to the negative environment on the team, because he "… echoed the head coach," (ID 30) and often emphasized body shape, making comments about competitors' body weight, such as "… oh look at her she's thick, and look at her she's really thin" (ID 30).

Coaches' attention to and open dialogue about body weight and size, added to women's overall anxiety about their body image and performance. One woman described, "Seeing my coaches, thinking what they thought of me, for sure noticing everything I ate, it was just going in and talking to them about races, anxious about racing, literally I came to hate the sport" (ID 11). Another woman shared the discomfort and anxiety she felt after a coach asked her parents' permission to talk to her about food choices, explaining, "… my parents told me later that he had asked permission to talk to me about that, which kind of got to me, because that was when I knew my coach was looking at my body. I always in workouts thought of what he was thinking about my body." (ID 18)

Coaches used shame tactics to monitor athlete's food intake by controlling meals and food choices available to the team, especially while traveling for competitions and races. When the coaches were around, and food was present, women described examples of verbal and physical control that coaches took to shame women's eating behaviors and food choices. One woman explained, "… we had to be very particular about the places we ate when we traveled" (ID 9) and shared a scenario in which her coach was "… explicitly food shaming" (ID 9) a teammate in front of an entire restaurant, requiring that the teammate order a smaller sized meal. Another athlete described a similar food shaming experience that affected her teammates:

> "We would be out to eat for a meet or something out of town, if we would order something she didn't approve of she would change our order for us or take stuff off our plates we weren't allowed to eat. You had to be careful around campus, if she saw you eating somewhere she didn't think was good, she would say something for sure." (ID 43)

It appears the coaches used control over food and body image as an attempt to control team performance and may not have recognized the true harm in that approach. Overall, the power dynamic between the coach and athlete created an environment where women sought consistent validation from the coaches as a way to feel like their hard work was being seen and recognized. Coaches used that to their advantage and withheld communication and attempted to influence body weight and size as a means to achieve desired performance outcomes. When women did not receive attention from coaches, they fostered resentment towards their coaches that greatly influenced their stress and overall mental health.

Discussion

Overall, this research highlighted cultural and environmental risk factors for disordered eating and Triad/RED-S in the sport of long distance running. Two primary themes with subthemes emerged from the data: sport body ideals and the coach-athlete relationship and

power dynamic. As it was unclear which theme preceded which, the current paper presents the themes without attention to their particular order. It is not clear whether sport body ideals and culture of running influences coaching culture, or if the coaches, who maintain positions of power in the sport, perpetuate the culture. These themes likely feed into each other and reinforce the existing and dominant mentalities of the sport.

Sport Body Ideals

It was evident that participants felt the sport of Cross Country had and continues to have cultural ideals and values that encouraged the pursuit of body ideals that are often harmful for athletes. This sport culture promotes a specific physical aesthetic that is unattainable for many women, this "runner body" ideal, that is thought to be a perquisite to sport success. Further, this body ideal came to represent a very literal physical embodiment of an athlete's dedication and commitment to the sport.

Specifically, women described a culture that encouraged and normalized restrictive eating in pursuit of both ideal aesthetic with the promise of improved performance. Based on these findings, we identified four sub-themes within running culture to be further described.

The first is the *ideal "runner body*," or structures/factors in the sport that enable women to engage in disordered and/or restrictive eating and encourage perfectionist ideals that extend to the physical body. That culture allows these behaviors—potentially harmful behaviors—to go unquestioned and, often, they are even encouraged. These findings were consistent with previous studies on eating disorder risk factors in female athletes.[9,18] Sherman and Thompson (1995) emphasized that body-type ideals may be heightened among elite athletes, as they often embody perfectionist attitudes that extend to their physical bodies.[18] Most women expressed that the norm

in running community was to strive for both thinness and strength for sport performance and held the achievement of the largely unattainable runner body-ideal as a perquisite to success. Prior research has shown the harm in subjecting the body to the pursuit of thinness concurrent with the pursuit of strength and sport performance, because thinness and strength represent physiologically opposing demands.[20,21] Further, Markula (2016) described this female athlete body paradox as a "series of contradictions," where women are expected to be "firm but shapely, fit but sexy, strong but thin".[20] To achieve this "series of contradictions," female athletes are put at risk of employing a combination of unhealthy and physiologically harmful tactics, including undereating, diet plans, and exercise beyond what is required of their sport training.[22,23]

Notably, most women identified some type of disordered or unhealthy mentality in the culture of distance running that promoted under-eating and/or overtraining to purse a particular physical aesthetic. Further, these behaviors have manifested as unspoken rules of the sport that have been normalized and the expected part of the sport experience and training process. Research has shown that athletes may misunderstand the risk associated with their own adherence to rigid eating and exercise behaviors, given a sport culture that conflates these behaviors with discipline and dedication;[24] athletes may fail to recognize their own eating disorder and disordered eating behaviors, because low body fat levels are "… often required for participation" in elite sports and lead an athlete to believe that these behaviors are acceptable or even "normal".[24]

The second—sport mentality that promotes a notion that *"lighter is faster"*—conflates lower body weight with improved sport performance. That message was engrained in runners from a young age, and the "lighter is faster" messaging is everywhere from race t-shirts to water bottle stickers. Interestingly, women seemed to both adopt and reject this mentality,

simultaneously citing the physics of running, that higher body weight correlates with slower performance, while understanding that weight loss is unsustainable and often followed by eventual performance and health consequences. [25-27] Importantly, these interviews with female athletes showed that the "lighter is faster" idea was learned early on in women's lives, and it is notable that some participants were introduced to the "lighter is faster" mentality around the time of puberty, a natural body weight and shape changes, which caused women to fear this vital stage of development and internalized shame around the healthy weigh-gain associated with puberty. That is an important theme to understand for prevention and intervention efforts.

The last subtheme is the *event-type body identity,* reflected in the women's comments about differences body ideal and eating mentality for middle distance versus long-distance race groups. To our knowledge, this is the first paper to identify discrepancies in within sport body ideals for female runners, as opposed to literature that groups all runners into "leanness" sport category.[28] Our study identified differences in body ideal by event-type, where participants competing in middle distance track and field events, in addition to cross country, identified as having and desiring a more muscular aesthetic as part of their personal thin "runner body" ideal. Described as muscular, yet very lean, these middle-distance runners appeared to have pride in their lean-muscle, which they attributed to the different types of workouts they completed during track season. Importantly, many women talked about the distinction in physical appearance between the middle distance and long-distance runners as signaling and distinguishing their identity, and even components of their personality. The difference in physical aesthetic between event groups seemed to be an unspoken communication of an athlete's identity within the sport of running, and even behaviors and mentality about diet and training. This finding was consistent with research on sport-specific body ideals, with leanness sport athletes having greater weight-

preoccupation.[18,29] Middle distance athletes seemed to believe that, overall, their event group had a healthier and more balanced mentality about body weight and size, given their emphasis on strength, yet they faced internal conflict with the transition to Cross Country season and racing with the long-distance event group. Having strong professional middle-distance female role models appeared to have a positive influence on body ideals in this event group. A conflict arose when women, competing in both middle and long-distance events, made a switch from track into Cross Country season, where the long-distance body type was now reinforced. Women who naturally embodied a more muscular build were then met with internal and external pressures to subscribe to a body type that may not have been healthy for them. When women middle-distance runner to not fit into the long-distance body ideal, they appeared to hold onto their middle-distance athlete identity to "explain" their physical aesthetic.

Interestingly, women described an ideal body that was thin but not too thin, and strong but not too strong, and they discussed the "fine line" between "looking healthy" and looking "skinny." This demonstrated that participants conflated external physical appearance with health and failed to take physiological and psychological components of health and wellbeing into account. That was consistent with Markula (1995), who described the expectation of the female athlete body, to be strong but not too muscular, as "the double body image" standard that both empowered and repressed women.[20] Surprisingly, very few women mentioned wanting to achieve the traditional "cultural thin-body ideal," promoted in popular media, but instead idealized the athlete "runner-body" ideal. That finding was contrary to previous work suggesting that female athletes were influenced by both cultural level messages that promoted thinness, in addition to sport-specific body ideals.[18] That discrepancy could be due to the fact that the runner ideal is not

far from the cultural thin-body ideal, as compared to other female sports that have greater body size and shape diversity.

The Coach-Athlete Relationship and Power Dynamic

The coach-athlete relationship was a powerful theme that emerged in the data and warrants immediate attention in the sport community. The majority of women described very different sentiments about their high school coaches as compared to their college coaching staff. Many women viewed their high school coaches as life-long mentors, and they still had relationships with them to this day; however, women's relationships with their college coaches evoked strikingly different responses, with the majority describing those relationships with a much more anxious tone and others with strong resentment. The collegiate coach-athlete relationship appeared to be much more serious and dynamic, where the tone was focused on performance outcomes and much less on building personal relationships or mentorship. The women reported an alarming level of emotional manipulation from college coaches, while simultaneously seeking the affirmation from coaches.

One significant source of psychological stress seemed to stem from athletes' desire to gain praise and validation from college coaches in a way that was closely tied to athletes' sense of self-worth. Unfortunately, many athletes revealed how college coaches would withhold communication as a form of punishment when the team or individual athletes did not meet a coach's expectations. The data clearly showed that this relationship was met with serious distress for many women, perhaps to the point of causing psychological harm for the athletes. It is vital that this degree of negative emotional manipulation is not ignored or downplayed. Further, coach's comments about body weight and shape added additional pressures to women who were

subjected to these comments. We found that women reported body weight and food related comments as a significant source of resentment towards their coach. It was well understood in the running community that particular coaches were known for body shaming comments, and some women shared that those comments were often a topic of gossip at races and competitions. Coaches used food shaming tactics to discourage consumption of particular types of food and quantities of food, and that often occurred while traveling together as a team. Even when body weight and shape comments were not directed at participants specifically, hearing these comments added to women's overall anxiety about body image and performance, as they feared future commentary on their body and acted in ways to avoid this from happening. Importantly, women described how the coaches' comments about body weight and size contributed to a harmful team environment.[28,30] Importantly, such comments were reported to be incredibly influential on an athletes' eating and exercise behaviors.[18]

Given the recent attention that Nike has garnered from coach maltreatment of athletes in the Nike elite running program, the current results are particularly timely. The importance of these findings, coupled with recent media attention on cases such as Mary Cain's [2], call for an urgent need for additional research regarding structural factors relating to coach-athlete dynamics and the provision of resources and psychological support services for athletes. This future work must take place within a larger cultural shift in body image expectations and/or coaching mentality/incentives; without that, these two major themes will persist. Yet, these themes are unlikely to change without higher-level systemic and structural changes that encourage a shift of priorities to wellbeing, with less focus on "winning;" a move that seems unfathomable in modern society, given the money and power that are tied to collegiate sport. Disordered eating and relative energy deficiency are not unique to collegiate runners, yet this

high-risk population is well-defined and contained within the regulated body of the NCAA, making them a population with significant potential for further research, and ultimately, early prevention and evidence-based interventions. Knowledge gathered in that population can be translated into the creation of a prevention and intervention frameworks for future generations of female athletes. Therefore, the current findings can be readily implemented via early prevention and intervention efforts among this population of NCAA female distance runners, given the resources of the NCAA and its member institutions.

Strengths and Limitations

To our knowledge, this is the first qualitative study investigating factors contributing to the onset of disordered eating and body image, and resulting psychological and physical health consequences, in NCAA DI female distance runners. Strengths of this study include the use of validated screening surveys prior to participation. Despite the convenience sampling scheme, women represented 19 colleges and universities from diverse geographic regions of the United States. Strengths of the analysis include transcription by hand to minimize errors of software-based transcription services, as well as double coding by the PI and a trained student research assistant. Despite strengths, there are important limitations of this study. The study sample was limited to interviews with 29 current and former NCAA DI Cross Country runners. It is possible that women with more severe experience with the topics of interest may have been more motived to share their experiences and participate in the interview. If so, this subset of women and may not represent the experiences of the "average" DI female Cross Country runner. Future research should include a more diverse sample of athlete experiences based upon population-based samples. Another potential limitation of the study comes from the use of two different data

collection modes—in-person interviews and video conference interviews. While these options were used to reach a more geographically diverse sample of participants, this may have created a bias if participants were more comfortable sharing their personal experiences via in-person versus video interviews. Future research including athletes in additional collegiate sport divisions, as well as high school and post-collegiate distance runners, is needed to better understand the experience of female distance runners across their careers. As women continue to engage in this sport, more follow-up research is warranted to understand the positive and harmful aspects of the sport experience for female athletes, in order to best serve the mental and physical well-being of athletes in current and future generations. We encourage continued advocacy for athlete-centered approaches to coaching and training that prioritize athlete's lifelong health and wellness.

Conclusions

To our knowledge, this study was the first qualitative study to examine factors contributing to the onset of disordered eating and body image disturbance in current and former NCAA DI female distance runners. The findings revealed that in the culture of female distance runners, body-image norms and myths persist, and the power dynamic between coach and athlete may contribute to a female athlete's risk of disordered eating and body image disturbance, resulting in adverse health consequences. A significant opportunity presents for the NCAA and athletic departments to development and implement further research on this topic, as well as prevention and evidence-based intervention programs to prevent eating and body image disorders in this high-risk population.

Table 2.1. Qualitative Study Example Questions

Category	**Example Question**
Body image	"What was your relationship with food and body image like throughout your life?" and "What types of messages have you received from coaches and/or teammates about body size/weight?"
Eating behaviors	"What types of food rules have you followed in the past, or are currently following?"
Nutrition education	"Growing up, did you ever learn about 'proper' nutrition for athletes? From whom?"
Menstrual and reproductive health	"Have you ever missed periods for reasons other than birth control/pregnancy? How did you react? and What type of birth control have you used in the past? How long and when?"
Injury history	"What sport-related injuries have you experienced?"
Help-seeking behaviors	"Have you ever seen a nutritionist or therapist? What was that experience like for you?"

Table 2.2. Age and Average Low Energy Availability in Females Questionnaire (LEAF-Q) and Female Athlete Screening tool (FAST) Scores for Study Participants

	Interview Sample (N=29)	Eligible Non-response (N=23)	Eligible Unable to Schedule (N=7)	Total eligible women who did not participate (N=30)	**Total Eligible Sample (N=63)**	Ineligible Sample (N=15)
Mean age (years) (range)	**24.6** (18-36)	24.0 (18-48)	24.6 (21-40)	27.7 (18-48)	25 (18-40)	23.5 (19-31)
Mean LEAF-Q Score (range)	**12.8** (7-19)	11.0 (5-18)	11.2 (7-18)	11.4 (5-18)	11.9 (7-19)	9.8 (3-24)
Mean FAST Score (range)	**74.4** (51-105)	69.6 (49-99)	71.3 (61-101)	72.7 (49-101)	72.1 (79-105)	70.9 (42-105)
Universities represented	**19**				24	

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Chapter 3

Identifying Latent Classes of RED-S Consequences in A Sample of NCAA DI Female Cross Country Runners

Abstract

Objective: The purpose of this study is to identify patterns of clustering of the ten health consequences of the Relative Energy Deficiency in Sport (RED-S) framework among collegiate female Cross-Country runners. Additionally, we assessed characteristics associated with each cluster.

Methods: This random sample included 211 current National Collegiate Athletics Association (NCAA) Division I (DI) female Cross Country runners from the Female Athlete Study of Health Trajectories. Participants completed a self-administered survey regarding RED-S consequences, demographics, personal information, disordered eating and emotional health. We used latent class analysis (LCA) to group athletes into mutually exclusive classes based on shared characteristics or response patterns of RED-S consequences. We computed bivariate descriptive statistics for demographics (age, race, ethnicity, socio-economic status), personal characteristics (abuse history, contraceptive use), disordered eating (drive for thinness, cognitive restraint) and emotional health (perfectionism, emotion regulation) variables by class.

Results: The average age of the sample is 21 years old, and the majority were White (87%), non-Hispanic (90%), Heterosexual (93%), and of comfortable (58%) or well to do (23%) socio-

economic status. The LCA identified three distinct classes. All classes were characterized by high levels of menstrual disturbance. Further, class 1 (39% of the sample) is characterized by low psychological concern as well as low concern on many physical aspects. Latent class 2 (16% of the sample) is characterized by a complex set of physical health concerns across most domains, including high cardiovascular, hematologic and menstrual concern, as well as medium to medium-high psychological concerns and medium-high bone, and gastrointestinal concern, growth and development and metabolic concerns are medium-low in this class and there is low immune and endocrine concern. Latent class 3 (45% of the sample) is characterized by the defining feature of high anxiety, medium-high menstrual, bone, and gastrointestinal concern, medium hematologic and depressive concerns, medium low growth and development, and low immune, endocrine, cardiovascular and metabolic concern. The descriptive analyses presented evidence of significant differences between the classes in terms of abuse history, emotional regulation and perfectionism.

Conclusion: This study identifies an overall high burden of menstrual disturbance in this population of NCAA D1 Cross-Country runners, and three unique presentations of RED-S consequences. Future research is warranted to better understand how early prevention and intervention strategies can be implemented to mitigate RED-S consequences in this population of NCAA DI female Cross Country runners.

Introduction

In 1993, the American College of Sports Medicine (ACSM) published the first position paper on the state of female athlete health, identifying a constellation of conditions termed the Female Athlete Triad (Triad).[1–3] The Triad consisted of three syndromes - menstrual disturbance,

low bone mineral density (BMD), and low energy availability (EA), commonly occurring in young female athletes.[4] Low energy availability (EA) is a physiologic state that occurs when there is a mismatch between caloric energy intake and exercise energy expenditure, resulting in inadequate energy to support the functions required by the body to maintain optimal health and performance,[5] the Relative Energy Deficiency in Sport (RED-S) framework expanded beyond the Triad to address the harmful effects of low EA on aspects of physiological function including menstrual function, bone health, metabolic rate, endocrine, hematologic, immune, cardiovascular and psychological health, as well as growth and development (Figure 3.1.).[5] In a clinic based study of adolescent female athletes, that those with low EA were more likely to experience menstrual dysfunction, poor bone health, metabolic issues, hematological detriments, psychological disorders, cardiovascular impairment and gastrointestinal dysfunction, as compared to peers with adequate EA.[6]

Collegiate female athletes represent a high-risk population for RED-S, given the dual pressures of excelling at sport and academic work, as well as high rates of disordered eating among college students.[7] The epidemiology of the Triad and RED-S in collegiate female athletes is not well understood, given organizational limitations on accessing this population for research purposes. However, one longitudinal study assessed Triad outcomes among athletes at Stanford University (n=323) and found that 27% of women reported menstrual disturbance, 6% met criteria for low BMD, and 16% reported at least one stress fracture or bone stress reaction.[8] This same study reported that the burden of stress fractures was as high as 34% among collegiate female cross country athletes.[8] Beyond the Stanford study, no other research has evaluated the burden of RED-S in collegiate female athletes, despite the large size of this population.

There are over 15,000 female collegiate Cross-Country runners in all divisions of NCAA, and approximately 6,000 competing in NCAA DI each year.[9] While RED-S is not unique to collegiate runners, these athletes represent a vulnerable population for RED-S, given the significant demands and pressures to excel at sport and academics, in addition to factors that affect all females, such as pressures to meet the societal "thin" ideal and lack of resources and access to mental health and emotional support services. Further, this population of collegiate female runners is well-defined and contained within the regulated body of the NCAA, making them a population with significant potential for early prevention and intervention. Knowledge gathered in this population can inform prevention and intervention frameworks for future generations of female athletes. Thus, given the lack of scientific understanding of RED-S in the college athlete population, the purpose of this study is to identify how the ten health consequences of the RED-S framework cluster together among National Collegiate Athletic Association (NCAA) Division One (DI) female distance runners.

Methods

Study Design and Protocol

Participants, Source Population and Probability Sampling

This sample included 211 participants from a nationally representative, random sample of current NCAA DI female Cross Country runners from the Female Athlete Study of Health Trajectories (FASHT). To create this sample, a simple random sampling approach was implemented among current NCAA DI female Cross Country runners from across the country. The sampling frame included approximately 6,000 female Cross-Country runners from 352 teams. This sampling frame was constructed by collecting 2018-2019 rosters from all NCAA DI

female Cross Country teams in the United States. Two teams did not have publicly available rosters and were not included in the sampling step. Of those that had rosters available, five women from each team were randomly selected using a random number generator, resulting in a sample of 1750 women to be contacted via email and invited to participate in the study. Of the selected women, 881 (50.3%) had unavailable or invalid email addresses, collected from publicly available sources on the respective University's websites. Of the 869 sampled women who could be contacted via email, a total of 180 responses were received, resulting in a response rate of 21%. This sampling process was repeated, selecting five more women from each team when available, as some teams did not have 5 additional women on the roster. This second sample included an additional 1117 women, of whom 758 (68%) had unavailable/invalid email addresses. Of the 359 women contacted in the second sample, 42 responses were received (response rate 6%). A total of four follow up emails were sent to each selected participant, in two-week increments, to athletes who were non-responsive to prior contact attempts. Our first round of sampling yielded a response rate (21%), which is on the lower end of the response rate reported by other studies of cold-calling internet surveys among college students (20-30%) [10]; however, response rates in round two of our study was much lower. Of the 222 total responses, data from 211 women who completed at least 40% of the survey was retained in for analysis.

Women who were invited to participate and completed the demographic data section of the survey but did not complete enough of the survey to be included in the analysis (n=161) did not differ significantly on demographics variables compared to those who were included in the final study sample.

Eligibility Criteria

To be eligible for the study, athletes had to be currently competing and/or have competed in at least one full season of Cross Country at a NCAA DI institution and be on the roster for the 2018-2019 season. Women were excluded from the study if they self-reported currently undergoing in-patient treatment for eating disorder and/or other psychological disorders.

Survey Overview

Self-reported survey data was collected using the Qualtrics online platform from 2018-2019 and captured biological, psychological, and sociological factors related to health, sport, injury history, academics and energy availability. Electronic informed consent was collected prior to participation in the survey. This study was approved by the University of Michigan Institutional Review Board.

Measures

RED-S indicator variables

Data from the FASHT self-reported survey was used to operationalize the ten health consequences of the RED-S model, and our approach was modeled after that of Ackerman et al., (2018). **Cardiovascular health** was measured using questions from the six-heart health section of the Pre-participation Examination – Fourth Edition [11], including the following binary questions: 'Ever passed out or nearly passed out during or after exercise'; 'Ever had discomfort, pain, or pressure in your chest during exercise'; 'Heart ever raced or skipped beats during exercise'; 'A doctor has ever ordered a heart test for you (EKG, ECG, echocardiogram)'; 'You get lightheaded or feel shorter of breath than expected during exercise'; 'You get more tired or short of breath more quickly than teammates during exercise.' Positive responses to ≥3 of six cardiovascular health questions classified the athlete as increased risk for cardiovascular health

consequences. **Menstrual dysfunction** was characterized by a "yes" to 'Did you have primary amenorrhea (menarche >age 15.0)' or 'Have you ever been unable to predict when your menstrual cycle will come?'), or a "no" to 'Are you currently getting regular periods?' or 'Have you had a period bleed about once a month since your first menstrual period?'. Poor **bone health** was defined as self-reported ≥1 sport-related bone injury (bone break, bruise, fracture, stress fracture, shin splints or other) in their sport history**.** Impaired **gastrointestinal** (GI) **health** was defined as a score of greater than 10 to the following questions from the Low Energy Availability in Females Questionnaire (LEAF-Q) [12]: 'Do you feel gaseous or bloated in your abdomen when you do not have your period?' (0= No, not at all, 1= Yes, once or twice, 2= Yes, three or four times, 3= Yes, five times or more); 'Do you get cramps or stomach aches that cannot be related to menstruation?' (1= 1-7 days, 2= 8-14 days, 3= 15-21 days, 4= 22 days or more); 'How often do you have bowel movements on average?' (3= Yes, several times a day, 2= Yes, several times a week, 1= Yes, once or twice a week or more seldom, 0= Rarely or never); and 'How would you describe your stool?' (0= Normal, 1= Diarrhea-like, 2= Hard and dry). Impaired **hematological health** was defined as a self-reported a history of anemia, low hemoglobin, iron or ferritin, and/or abnormal bruising. **Endocrine dysfunction** was defined as self-report of ever having an abnormal thyroid function test result.[6] **Metabolic dysfunction** was defined as self-report of ever having a low resting metabolic rate. Impaired **growth and development** was defined as self-report of 'falling below normal growth curves during childhood, as indicated by doctor'.[6] Poor **immune health** was defined as agreement or strong agreement to the statement "I seem to get sick more often than others".[13] **Psychological health** was considered as anxiety and depression separately. Anxiety was measured via the Generalized Anxiety Disorder Scale 7 (GAD-7) (4-level variable; 0-5= mild anxiety, 6-10= moderate anxiety,

and 11-15= moderate anxiety, 16-21 = severe anxiety).[14] Depression was measured by the Patient Health Questionnaire 8 (PHQ-8) (4-level variable; 0-5= mild depression, 6-10= moderate depression, 11-15= moderately severe depression, 16-20= severe depression).[15]

Demographics and Personal Characteristics

Individual level demographic characteristics included self-reported age, family socioeconomic status (very poor, had enough but not extras, comfortable, or well to do), sexual identity (heterosexual, bisexual, lesbian, questioning, asexual, other), gender identity (woman, other), height and weight (used to calculate body mass index (BMI) as weight (kilograms) ÷ height (meters^2)), race (White, Black, Asian, American Indian, Native American/Pacific Islander, Other, mixed), ethnicity (Hispanic/Latina, Non-Hispanic/Latina), and year in school. Current and past contraceptive use was defined by binary self-report.

Disordered Eating and Emotional Health

Disordered eating was assessed using the Eating Disorder Inventory Version 3 (EDI-3) Drive for Thinness (range 0-28)[16,17], and the Three Factor Eating Questionnaire (TFEQ, range 0-28) Cognitive Restraint Scale.[18] Both provide a continuous measure of disordered eating, and higher scores indicate greater level of disordered eating. Perfectionism was measured as a proxy for disordered eating, using the EDI-3 Perfectionism Scale (range 0-28), where higher scores indicate a greater level of perfectionism.[16,17] Lastly, Difficulties in Emotional Regulation Scale (DERS) Emotion Regulation Impulse was reported (scale 0-15), where lower scores indicate lower emotion regulation.[19]

Analysis

Statistical analyses were completed using R Studio. Descriptive characteristics (means and standard deviations for continuous variables and frequencies and percentages for categorical variables) were calculated for the full sample. Latent class analysis (LCA) was used to group athletes into mutually exclusive classes based on shared response patterns for the RED-S physical health variables. This data-driven and person-centered approach uses maximum likelihood estimation to derive classes of individuals from the observed data set based on the response patterns, and estimates the prevalence of each class.[20] Based on the estimated latent class model, each participant is assigned a predicted probability of membership in each class, and then assigned to the one latent class for which they have the greatest probability of membership.[21] The Bayesian Information Criterion (BIC), Akaike Information Criterion (AIC), maximum log-likelihood, and subject matter considerations were used to guide the final choice of the number of classes that best fit the observed data, while maintaining stable minimum class sizes (e.g., N>25).[22,23] Additionally, descriptive statistics were calculated for the individuals assigned to each class, including means and percentages for demographics, personal characteristics, disordered eating and emotional health. We then formally compared the derived classes in terms of these descriptive quantities using one-way analysis of variance and chi-square tests.

Results

The average age of the sample was 21 years old, and the majority of the respondents were White (87%), non-Hispanic (90%), Heterosexual (93%), and of comfortable (58%) or well to do (23%) socio-economic status, consistent with the demographic makeup of this population.[24]

Most women in the sample were upper-level undergraduate students and only 13% were graduate or professional students (Table 3.1.).

RED-S consequences were highly prevalent in the sample; three-quarters of women reported a bone injury (75%), and more than half reported hematologic issues (58%), gastrointestinal concerns (54%), and menstrual dysfunction (53%) and one-third (34%) reported cardiovascular consequences. High anxiety, defined as the highest quartile of the GAD-7 scoring scale, was present in 53% of women, and the mean GAD-7 score was 13.68 (moderate anxiety). The average depression score on the PHQ-8 was 13.33 (moderately severe), and 24% of women fell into the highest scoring category for depression. As shown in Table 3.2., other RED-S consequences were less common, ranging from 10% of women with endocrine consequences to 16% of women with reported impaired growth and development.

Latent Class Analysis

We tested models representing 2, 3, 4 and 5 latent classes; model fit statistics are shown in Table 3.3. A 3-class model was selected because it averaged as the best fit based on the specified model fit criteria (BIC, AIC, maximum log-likelihood, and subject matter considerations) (Table 3.2).

The three classes identified in the LCA analysis are shown in summary in Figure 3.2 and Table 3.4. The conditional probabilities of each indicator variable for each class were categorized as low (0.00–0.19), medium-low (0.20–0.39), medium (0.40–0.59), medium-high (0.60–0.79), and high (0.80–1.00) (Swanson, 2012). Importantly, no classes were characterized by low probabilities across all RED-S consequences.

Although endocrine concern was low and menstrual disturbance was high or medium-high across all three classes, there are notable differences in the patterning of the RED-S consequences across the latent classes. Latent class 1 (LC1), the "Low RED-S Consequence Class," representing 39% of participants, is characterized by low psychological concern as well as low concern on many physical aspects, but medium concern for gastrointestinal, hematologic, bone health. We consider LC1 the least severe RED-S class, despite notable menstrual health concern.

Latent class 2 (LC2), the "High RED-S Consequence Class," including 16% of women, is characterized by a complex set of physical health concerns across most domains, including high cardiovascular, hematologic and menstrual concern, as well as medium to medium-high psychological concerns and medium-high bone, and gastrointestinal concern. Growth and development and metabolic concerns are medium-low in this class and there is low immune and endocrine concern.

Latent class 3 (LC3), the "Anxious, High RED-S Consequence Class," which includes 45% of women, is characterized by the defining feature of high anxiety. Similarly, to LC1, LC3 has medium-high menstrual, bone, and gastrointestinal concern, with other factors including medium hematologic and depressive concerns, medium low growth and development, and low immune, endocrine, cardiovascular and metabolic concern.

In the overall test of class differences, there were statistically significant differences in class distributions for Emotion Regulation ($p=0.008$) and Perfectionism ($p<0.001$). There were significant pairwise differences for Emotion Regulation (LC1 > LC2, $p=<0.001$; LC1 < LC3 $p=<0.001$; LC2 < LC3, $p=<0.001$) and Perfectionism (LC1 < LC2, $p=<0.001$; LC2 > LC3, $p=<0.001$). Further, there were significant pairwise differences for Contraceptive Use (LC1 <

LC2, p=<0.001; LC2 vs. LC3, p=<0.001), and marginally significant differences for Contraceptive Use (LC1>LC3, p=0.085). Additionally, there were marginally significant differences for Year in School (LC1 < LC2, p= 0.054) and Racial diversity (LC1<.LC3, p=0.093). There were no significant pairwise differences between latent classes for demographic variables, such as ethnicity, age or SES (Table 3.1). However, LC3 was more ethnically diverse, relative to LC1 and LC2, and SES was marginally lower in LC2 compared to LC1.

Discussion

Overall, this study demonstrates that RED-S consequences are highly prevalent among NCAA D1 female runners. Over 50% of women in this sample reported experiencing a bone injury, cardiovascular, hematologic, or gastrointestinal concern, menstrual dysfunction, as well as high symptoms of anxiety. Notably, when examining clustering of these RED-S concerns, all classes were characterized by high levels of menstrual dysfunction. However, LC1 emerged as the class reporting the lowest probabilities of RED-S consequences whereas LC2 and LC3 had greater burden of RED-S consequences, differentiated by the extremely high anxiety complaints among LC3.

Unlike previous work which has focused on athletes from clinical samples [6], participants in this study were randomly sampled, and we did not seek out athletes with any particular history of medical or psychological outcomes. This suggests that RED-S concerns are broadly prevalent across NCAA DI female Cross Country runners, thereby indicating that there may be an unmet need of timely intervention and medical support. These preliminary findings warrant significant concern for both short- and long-term health and wellbeing of collegiate female runners and call for future research needed in this area.

We identified three latent classes, characterized by patterning of the probability of RED-S concerns. Despite some notable differences between the latent classes, we identified four RED-S health consequences, including menstrual disturbance, bone injuries, gastrointestinal and hematologic concern, that were of medium to high concern in all three classes. Further, two classes were characterized by medium or high probabilities of depression and anxiety, confirming the importance of psychological health in the RED-S framework. In all three classes, endocrine, immune and metabolic concern was medium low or low. We hypothesize that endocrine and metabolic consequences may have been underreported, due to the limitations in assessing these measures, as they were only indicated as "true" by self-reported clinical assessments of endocrine and metabolic markers.

Although the "Low RED-S Consequence Class" LC1 reported the lowest probabilities of RED-S consequences, they, like all classes, reported moderately high menstrual disturbance. Whether this group of women represents those inherently less affected by the RED-S consequences or whether women in this class are earlier in their progression to a fuller and more severe set of RED-S consequences observed among other classes is unknown. Future work is needed to understand whether women move from one latent class to another over their career, and if so, what the implications of these changes are for their overall health and well-being. The observed menstrual disturbance among this otherwise seemingly low burden class should not be ignored; identifying the root cause of menstrual disturbance is vital to ensure proper treatment.[2,25]

The "High RED-S Consequence Class" LC2 is characterized by a complex set of physical and psychological concerns, most notably higher burden of cardiovascular concern than the other two latent classes. Some research has shown impaired cardiovascular health in female

athletes with low EA and amenorrhea, including lower heart rates and systolic blood pressure compared to eumenorrheic athletes, early atherosclerosis, endothelial dysfunction and unfavorable lipid profiles.[26–28] Low EA, in a non-athlete populations with anorexia nervousa, is shown to be associated with severe cardiovascular concerns, including valve abnormalities, pericardial effusion, severe bradycardia, hypotension, and arrhythmias.[29] Additionally, hematologic and menstrual concern are known to be associated with low EA and disordered eating/eating disorders.[6,30,31] Anxiety, bone, and gastrointestinal complaints were an additional concern in this class, and may be associated with low EA; however, the temporality of these consequences is unknown.

The "Anxious, High Consequence Class" LC3 is characterized by very high probability of anxiety with additional high burden of the physiologic symptoms of menstrual disturbance, bone injury and gastrointestinal concern. Anxiety and psychological stress are known to be associated with menstrual disturbance and hypothalamic amenorrhea, in both athlete and non-athlete populations.[5,32–35] Further, gastrointestinal upset is known to be associated with anxiety and life stress among runners [36] and general adult populations;[37,38] however, the possible reverse causation between anxiety and gastrointestinal problems is unknown in this study. Clark & Mach (2016) highlight the need for continued research to understand the separate effects of physical and psychological stress on GI distress during exercise.[39]

In the overall sample, there was a high burden of psychological concern; Over 50% of the sample reported high scores for anxiety on the GAD-7. Despite high mean anxiety, scores for depression on the PHQ-8 were moderately severe, and 24% of women in this study reported severe depression scores; however, a 2017 study of NCAA DI athletes reported a higher rate of depression (37%) among female athletes.[40] Given the overall high burden of anxiety in this

sample, we hypothesized that the cardiovascular concern in the "High RED-S Consequence Class" may be capturing anxiety, similar to the "Anxious, High RED-S Consequence Class," but captured as cardiovascular complaints. Shortness of breath and difficulty breathing, known symptoms of anxiety, were also used to capture cardiovascular complaints.[41,42] However, at the item level, women assigned to the "High RED-S Consequence Class" did not show higher endorsement of those questions related to shortness of breath and difficulty breathing.

As noted, in all three latent classes, both bone injury and menstrual disturbance were of significant concern, and the harmful relationship between menstrual disturbance and subsequent bone injury and loss of bone mineral density is well known.[3,43,44] Additionally, bone injury may be a consequence of the nature of running mechanics and sport training load, and the annual incidence rate of bone stress injury is 20% among elite collegiate runners, and a Sandford study found that female cross country runners had the highest incidence of bone injury of any university sport [45,46]. However, this relationship may be at least partially explained by low EA, as this study also found an increasing risk of bone injury as EA decreased.[45,46]

Women in all three classes endorsed aspects of RED-S, these concerns should be evaluated and monitored, to safeguard athlete wellbeing. Further, it is important to ensure appropriate psychological health evaluations to consider disordered eating and eating disorders, and/or other psychological health concerns, that may be the underlying cause of these RED-S consequences.

Strengths

There are many strengths of this study, the most notable being the randomized sampling design. To our knowledge, this is the first true national, random sample and epidemiologic study

of NCAA DI Cross Country runners, or any NCAA sport. This sampling approach makes the study findings more representative and generalizable to the population of NCAA DI Cross Country runners. Understating how RED-S may present differently is vital to understating different approaches to acute treatment of RED-S; some athletes may be best suited for immediate medical care and testing, while others may benefit from psychological treatment in combination with need for physical health care.

Limitations

Despite notable strengths of this study, there are some important limitations to address. The self-reported nature of the survey data collection, particularly for medical and health related information, is subject to desirability bias, in addition to the cross-sectional nature of the survey that limits our understanding of temporal relationships between RED-S consequences. Further, selection bias may be present, despite the use of random sampling, women who participated in the study may have had a personal interest and/or personal experience with RED-S and a negative sport experience. If the final analytic sample included women with greater likelihood of having RED-S, this may have biased our findings and represent women with greater health concern and not the broader population of NCAA DI female cross country runners. of Additionally, selection bias may have impacted the latent classes we observed; we did not observe a true healthy class of athletes, and it is possible that women who would have been assigned to a true healthy class did not participate in the survey. Alternatively, we may not have captured women that would have been assigned to a more severe RED-S class, as compared to LC 2 and LC3, if these women dropped out of the sport prior to this study or were selected for the study but uninterested in participating. It is possible that women who had more severe RED-

S consequences experienced bone injury and/or other career-ending RED-S consequences, such as psychological health impacts, that removed them from sport, and therefore, they were not captured in our data.

It is important to note that some RED-S variables were particularly challenging to capture in a self-reported survey, and the consequences of endocrine and metabolic outcomes are of particular concern. These RED-S variables are likely underreported in this sample; consequently, these consequences were not showing up as concerns in the latent classes, but this may be due more to issues with self-reported proxy measures for endocrine and metabolic health markers that are commonly collected in clinical blood samples, rather than lack of importance. It is important that future studies improve methods of measuring self-reported RED-S consequences, particularly those that are not as apparent to an individual, unlike a broken bone or cessation of menses. Additionally, future studies are needed to better understand the temporal relationship between variable RED-S consequences; this can inform early intervention efforts of RED-S before subsequent consequences occur.

Conclusion

This study is identified three distinct latent classes of RED-S consequences in this population of NCAA DI female Cross Country runners. The "Anxious, High RED-S Consequence Class" highlights the need for further attention and treatment of psychological concerns in the population, the "High RED-S Consequence Class" is characterized by significant cardiovascular concern and several additional physiologic and psychological complaints, and "Low RED-S Consequence Class", the least concerning class, characterized by moderate menstrual concern. Future research is warranted to better understand how early prevention and

intervention strategies can be implemented to mitigate RED-S consequences in this population of NCAA DI female Cross Country runners.

Figure 3.1. RED-S Health Consequences Framework

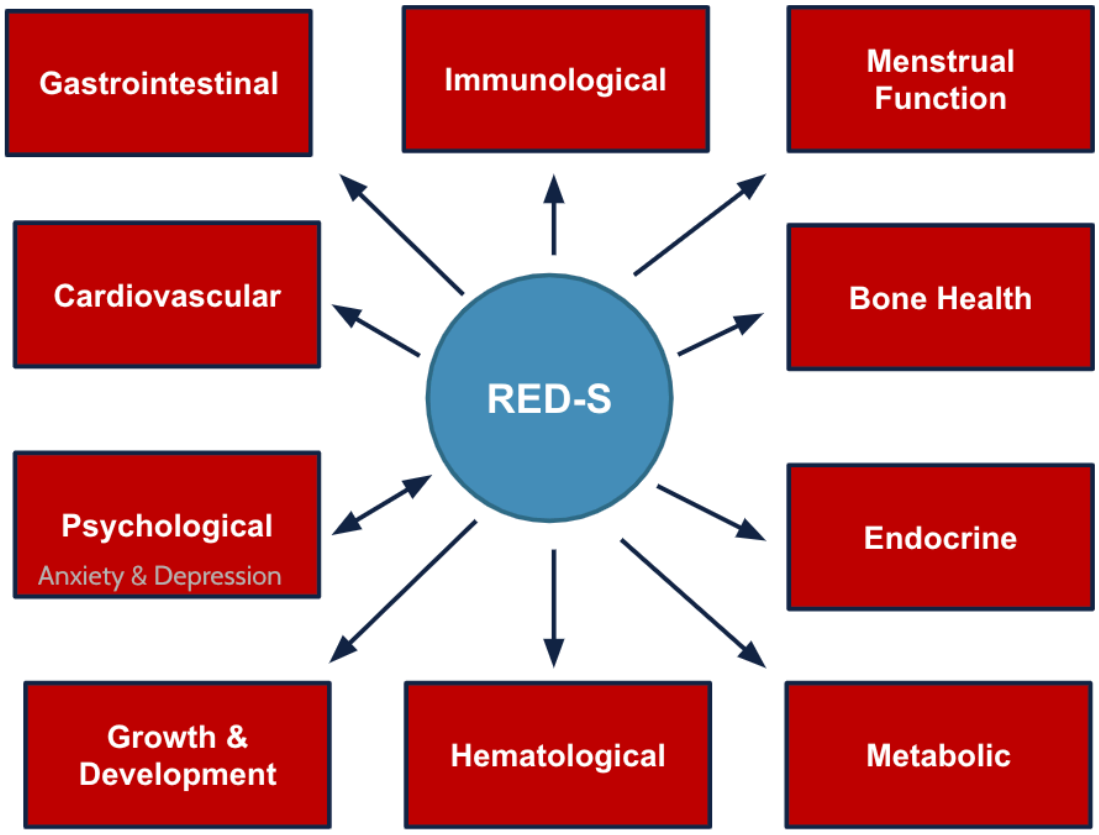
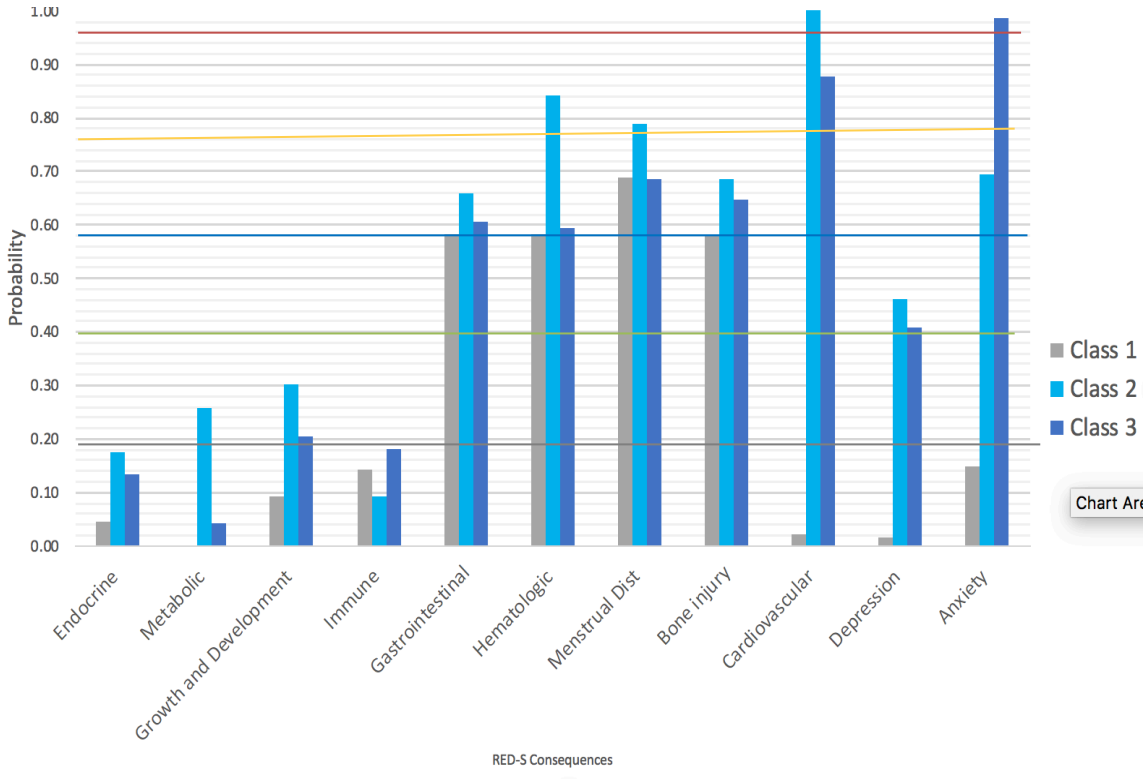


Figure 3.2. Latent Classes of RED-S Consequences



Key:
Class 1: "Low RED-S Consequence Class"
Class 2: "High RED-S Consequence Class"
Class 3: "Anxious, High RED-S Consequence Class"

Conditional probability thresholds:
Low (0.00–0.19) - Grey
Medium-low (0.20–0.39) – Green
Medium (0.40–0.59) – Blue
Medium-high (0.60–0.79) – Yellow
High (0.80–1.00) - Red

Table 3.1. Demographic, Disordered Eating and Emotional Health Characteristics by Latent Class

	Full Sample (N= 211)		LC1: Low RED-S Consequence Class (N=83)		LC2: High RED-S Consequence Class (N=34)		LC3: Anxious, High RED-S Consequence Class (N=94)		P-value	P-value	P-value	P-value
Demographics	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**Overall test**	**Low vs High**	**Low vs Anxious**	**High vs Anxious**
Sexual Identity*									0.738	1.000	0.247	0.639
Hetero	93%	197	95%	79	97%	33	91%	86				
Bi	4%	8	2%	2	0%	0	6%	6				
Lesbian	0%	1	1%	1	0%	0	0%	0				
Questioning	2%	5	1%	1	0%	0	0%	0				
Asexual	2%	5	0%	0	0%	0	1%	1				
Other	0%	1	0%	0	0%	0	1%	1				
Race *									0.405	0.210	0.093	0.072
White	87%	183	88%	73	88%	30	85%	80				
Black	2%	5	5%	4	0%	0	1%	1				
Asian	0%	1	1%	1	0%	0	1%	1				
American Indian	0%	1	1%	1	0%	0	7%	7				
NA/ PI	5%	10	1%	1	0%	0	4%	4				
Other	5%	10	0%	0	6%	2	0%	0				
Mixed	10%	21	0%	0	0%	0	0%	0				
Ethnicity									0.320	0.718	0.319	0.758
Hispanic /Latino	23%	48	7%	6	9%	3	13%	12				
Not Hispanic /Latino	58%	122	93%	77	91%	31	87%	82				
Family's current socioeconomic status									0.553	0.184	0.722	0.574
Well to do	23%	48	27%	22	15%	5	22%	21				

Comfortable	58%	122	60%	50	56%	19	56%	53				
Had enough, not extras	18%	37	13%	11	26%	9	18%	17				
Very poor	1%	3	1%	1	3%	1	2%	2				
Year in School									0.803	0.054	0.672	0.295
1st year undergraduate	1%	2	0%	0	3%	1	1%	1				
2nd year undergraduate	21%	45	24%	20	12%	4	22%	21				
3rd year undergraduate	30%	64	36%	30	29%	10	26%	24				
4th year undergraduate	25%	52	24%	20	21%	7	27%	25				
5th year or more undergraduate	6%	13	4%	3	12%	4	6%	6				
Graduate or professional student	13%	27	10%	8	24%	8	12%	11				
Contraceptive Use	48%	101	27%	22	71%	24	16%	15	0.212	**0.000**	0.085	**0.000**
Abuse History	29%	61	40%	33	29%	10	19%	18	0.955	0.603	0.593	0.365
			Mean (SD)	**Range**	**Mean (SD)**	**Range**	**Mean (SD)**	**Range**	**P-value**	**P-value**	**P-value**	**P-value**
Age	21.33 (1.25)	(19-25)	21.24 (1.23)	(19-24)	21.67 (1.32)	(19-25)	21.24 (1.23)	(19-24)	0.862	0.096	1.000	0.089
BMI	20.4 (1.59)	(16-26)	20.53 (1.75)	(16-26)	20.41 (1.36)	(16-25)	19.98 (1.45)	(17-24)	0.462	0.656	0.754	0.803
TFEQ: Cognitive Restraint (0-28)	10.58 (1.18)	(9-12)	17.97 (1.16)	(14-23)	17.58 (1.21)	(14-24)	18.02 (1.16)	(13-31)	0.461	0.106	0.775	0.063
EDI: Drive for Thinness (0-28)	4.32 (3.61)	(0-12)	4.21 (3.61)	(0-12)	4.07 (3.65)	(0-11)	4.21 (3.56)	(0-11)	0.434	0.850	1.000	0.846
DERS: Emotion	5.06 (3.14)	(3-15)	5.78 (3.32)	(3-15)	3.43 (2.58)	(3-15)	10.57 (3.32)	(9-12)	**0.008**	**0.000**	**0.000**	**0.000**

Regulation Impulse (0-15)												
EDI Perfectionism (0-30)	18.97 (4.14)	(7-30)	18.58 (4.36)	(7-30)	21.73 (2.76)	(11-30)	17.64 (3.04)	(10-25)	**<0.001**	**0.000**	0.095	**0.000**

*not mutually exclusive

Table 3.2. RED-S Health Consequences by Latent Class

	Full Sample		Low RED-S Consequence Class (N=83)		High RED-S Consequence Class (N=34)		Anxious, High RED-S Consequence Class (N=94)		
RED-S Consequences	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**P-value**
Anxiety (high)	13.68	mean score	82%	77	68%	23	13%	11	0.773
Depression (high)	13.11	mean score	35%	33	47%	16	1%	1	0.719
Hematologic	58%	126	44%	41	91%	31	57%	47	0.773
Bone injury	75%	160	62%	58	65%	22	49%	41	0.236
Menstrual Disturbance	53%	112	41%	39	47%	16	40%	33	0.863
Cardiovascular	34%	71	11%	10	94%	32	1%	1	0.065
Gastrointestinal	54%	115	39%	37	53%	18	19%	16	0.455
Endocrine	10%	21	12%	11	21%	7	4%	3	0.0723
Growth and Development	16%	34	18%	17	29%	10	10%	8	0.511
Metabolic	14%	30	3%	3	26%	9	0%	0	0.271
Immune	15%	31	13%	12	6%	2	5%	4	0.533

Table 3.3. Latent Class Analysis Model Fit Statistics

Fit Statistics	**5 class**	**4 class**	**3 class**	**2 class**
Maximum log-likelihood	-868.4776	-1058.734	-1058.335	-1075.046
AIC	2217.423	2205.467	2204.67	2208.091
BIC	2467.194	2353.98	2353.182	2305.974

Table 3.4. Probability of RED-S Consequence by Latent Class

Low RED-S Consequence Class	**Pr.**
Menstrual Dist	0.69
Gastrointestinal	0.58
Hematologic	0.58
Bone injury	0.58
Anxiety	0.15
Immune	0.14
Growth and Development	0.09
Endocrine	0.04
Cardiovascular	0.02
Depression	0.01
Metabolic	0

High RED-S Consequence Class	**Pr.**
Cardiovascular	1
Hematologic	0.84
Menstrual Dist	0.79
Anxiety	0.69
Bone injury	0.69
Gastrointestinal	0.66
Depression	0.46
Growth and Development	0.3
Metabolic	0.26
Endocrine	0.18
Immune	0.09

Anxious, High RED-S Consequence Class	**Pr.**
Anxiety	0.99
Menstrual Dist	0.69
Bone injury	0.65
Gastrointestinal	0.61
Hematologic	0.59
Depression	0.41
Growth and Development	0.2
Immune	0.18
Endocrine	0.13
Cardiovascular	0.12
Metabolic	0.04

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Chapter 4

Differences in Bone Injury Between Latent Classes Defined by RED-S Consequences in a Sample of NCAA DI Female Cross Country Runners

Abstract

Objective: The purpose of this study is to examine the association between latent class membership and bone injury outcomes in a population of current National Collegiate Athletic Association (NCAA) Division One (DI) female cross country runners.

Methods: The sample included 211 participants from a national, random sample of current NCAA DI female Cross Country runners from the Female Athlete Study of Health Trajectories (FASHT). We performed latent class analysis (LCA) in MPlus to fit a 3-class model of Relative Energy Deficiency in Sport (RED-S) consequences, including menstrual function, bone health, endocrine, metabolic, hematological, growth and development, psychological, cardiovascular, gastrointestinal, immunological health. We used Chi-Square tests to assess the relationship between latent class membership and bone injury outcomes (bone injury, bone stress fracture, and shin splints) ever, and during their collegiate career.

Results: We identified three latent classes representing clustering of RED-S consequences; yet, menstrual disturbance, bone injuries, gastrointestinal and hematologic concern were of medium to high concern in all three classes. Latent Class (LC) 1, the "Low RED-S Consequence Class", represents 38% (n=80) of participants and characterized as the least severe class; LC2, the "High RED-S Consequence Class", represents 37% (n=79) of participants and characterized by a

complex set of physical health concerns across most domains, as well as medium to medium-high psychological concerns; and LC3, the "Anxious, High RED-S Consequence Class", represents 25% (n=52) of participants and is characterized by high anxiety along with a complex set of physical health concerns across most domains. Notably, all three latent classes are characterized by a medium-high burden of menstrual disturbance. Participants reported 122 total bone injuries over the course of their athletic careers; 57.3% of athletes (n=121) reported at least one past bone injury. Of all reported bone injuries, 82.6% (n=100) occurred during college; 34.6% (n=73) of women reported a bone stress fracture during college, 9% (n=19) reported shin splints during college, and < 3% reported a bone bruise (n=6), a bone break (n=3) or bone fracture (n=2) during college. We observed no statistically significant difference in the burden of bone injury between the three latent classes.

Conclusion: There is a high burden of bone injury in this population of NCAA D1 female Cross-Country runners, with the majority of injuries occurring during college. Women exhibited a similar burden of bone injury across all three latent classes. Future longitudinal studies are needed to better understand causal relationships between features of RED-S and bone injury outcomes.

Introduction

The combination of energy availability, neuroendocrine health, and the nature of mechanical loading determine the impact of exercise on bone health [1–3]. Athletes with adequate energy availability (EA) may experience enhanced bone health, due to the benefits of mechanical loading inherent to weight bearing exercise.[1] However, athletes in endurance sports and sports that emphasize leanness, such as running, may have impaired bone density due to their increased

risk of low EA;[4,5] as such, low EA can negate potential benefits of exercise.[1–3] Athlete bone health during the young adult years is of particular concern; disturbances to bone accrual and formation are largely irreversible and have life-course implications on osteoporosis and injury risk.[6]

Bone injury is a core concern of the Female Athlete Triad (Triad) and International Olympic Committee's (IOC) Relative Energy Deficiency in Sport (RED-S) framework.[7,8] However, existing research on RED-S has not examined how bone injuries are associated with other RED-S consequences beyond what is known with respect to low EA and menstrual disturbance.[7,8] The annual incidence of bone stress fractures is reported to be as high as 20% among female runners.[9] One study of college female athletes at one university reported the burden bone stress injuries among cross country runners was as high as 34%, and cross country athletes accounted for the majority of all bone stress injuries across 16 sports.[10,11] In this same study of university athletes, almost half of cross-country athletes reported having all three syndromes of the Female Athlete Triad, including bone injury, in addition to low EA and menstrual disturbance.[10]

The vast majority of studies on bone health in female athletes, especially female collegiate athletes, focus solely on stress fractures or measures of bone mineral density, but little is known about other types of bone injury that may be affecting performance and wellbeing in this in this population.[12–18] Only one study of National Collegiate Athletic Association (NCAA) cross country runners captured all sport related injury, including additional bone injury subtypes such as, shin splints, bone fracture, and bone bruise.[19] This study reported a lower burden of bone injury than what has been previously reported in youth and elite populations, and this inconsistency warrants further investigation.[19] The overall lack of research on NCAA female

distance runners greatly limits our understanding of the burden of bone injury, particularly beyond what is known about stress fractures.

Little research has examined the relationship between RED-S consequences and bone injury outcomes. It is not understood how RED-S consequences, and latent classes of RED-S consequences, may be associated with bone injury. Therefore, the purpose of this study is to examine the association between latent classes of RED-S consequences and bone injury outcomes, including bone stress fractures, bone fracture, shin splints, and bone bruise, in a population of current NCAA Division One (DI) female cross country runners.

Methods

Study Design and Protocol

Participants

This sample included 211 participants from a national, random sample of current National Collegiate Athletic Association (NCAA) Division One (DI) female Cross Country runners from the Female Athlete Study of Health Trajectories (FASHT). The recruitment methods for FASHT have been described previously.[20] In brief, the sampling frame included approximately 6,000 female cross-country runners from 352 teams and was based on the 2018-2019 rosters from all NCAA DI female Cross Country teams in the United States. Ten women from each team were randomly selected for an invitation to participate. Women were eligible if they were currently competing and/or had competed in at least one full season of Cross Country at a NCAA DI institution; women were excluded from the study if they self-reported current in-patient treatment for eating disorders and/or other psychological disorders. A total of 373 women

responded to the participation invitation; of those, 211 women had contributed enough information for analysis and thus reflect our analytic sample (17% response rate).

Measures

The survey asked questions regarding RED-S consequences, demographics, personal information, disordered eating and emotional health.[20] Variables included as latent class indicator variables representing the health consequences of the RED-S model included cardiovascular health, menstrual function, gastrointestinal health, metabolic function, growth and development, immune health and psychological health including depression and anxiety as separate constructs. Despite being part of the RED-S framework [21], we did not include bone health, because this was our primary outcome of interest. Details of these measures have been previously reported.[20]

We considered several sport-related bone injury subtypes as primary outcomes. Participants were asked to report past sport related injuries (up to 7 injuries total) over the course of their running careers, and to document the type of injury (bone stress fracture, bone fracture, bone break, bone bruise and/or shin splints) and the year that each injury occurred. Each sub-type of bone injury was considered as a yes/no variable for ever having that type of injury and yes/no having that type of injury during college.

Analysis

Latent class analysis (LCA) was used to group athletes into mutually exclusive classes based on underlying shared response patterns for RED-S consequences; each participant is assigned a probability of membership in each class and then assigned to the one latent class for

which they have the greatest probability of membership.[22] We used MPlus to fit a 3-class model based on findings from Carson et al. (2020), that used Bayesian Information Criterion (BIC), Akaike information criterion (AIC), maximum log-likelihood, and subject matter considerations to select this 3-class model fit.[23]

Descriptive statistics of each bone injury type were calculated overall and by each latent class. Chi-Square analyses were used to assess differences in the distribution of each type of bone injury across the three latent classes, as well as pairwise comparisons of latent classes; MPlus accounts for the uncertainty in the predicted latent classes for individual cases for distal outcomes that are predicted by the latent classes.[24] Bone breaks, bone fractures and bone bruises were not included in the analyses due to a low number of reported events (n = < 10).

Results

As shown in Table 4.1, our analyses identified three latent classes representing clustering of RED-S consequences; all three classes were characterized by medium to high concern for menstrual disturbance, bone injuries, gastrointestinal and hematologic concern. Latent Class (LC) 1, representing 38% (n=80) of participants, is characterized as the least severe class, despite notable menstrual health concern; thus, we refer to this class as the "Low RED-S Consequence Class". LC2, representing 37% (n=79) of participants, is characterized by a complex set of physical health concerns across most domains, as well as medium to medium-high psychological concerns; thus, we refer to this class as the "High RED-S Consequence Class". LC3, representing 25% (n=52) of participants, is characterized by high anxiety along with a complex set of physical health concerns across most domains; thus, we refer to this class as the "Anxious, High RED-S Consequence Class". Notably, all three latent classes are characterized by a

medium-high burden of menstrual disturbance (>65% probability). The latent classes identified in this analysis are similar to those reported previously (Carson et al., 2020) when considering all RED-S consequences in this population.

More than half of women (n=121) 57.3% reported at least one bone injury over the course of their athletic careers, of those, 68.60% (n=83) reported a bone stress fractures, 19.0% (n=23) reported shin splints, 3% (n=7) reported a bone bruise, and < 3% reported a bone break (n=5) or bone fracture (n=4). Of all reported bone injuries, 82.6% (n=100) occurred during college; 34.6% (n=73) of women experienced a bone stress fracture during college, 9% (n=19) reported shin splints during college, < 3% reported a bone bruise (n=6), a bone break (n=3) or bone fracture (n=2) during college (Table 4.2). The distribution of bone injuries does not vary significantly by latent class; however, the "High RED-S Consequence Class" did have higher report of any bone injury (ever) but not for bone injury in college, as well as a slightly higher report of shin splints ever and during college (Table 4.3 and 4.4).

Discussion

In addition to the bone injury concerns highlighted in this study, findings from the LCA reinforce the high burden of RED-S consequences in this population. Each of the latent classes has distinct characteristics, yet all three have a moderate-high burden of menstrual disturbance. This finding is important to emphasize, given that menstrual disturbance is known to be associated with low EA, with or without disordered eating, and low bone mineral density.[2,3,25] It is not uncommon for athletes to experience menstrual disturbance as a result of disordered eating; one study of young adult female runners reported the prevalence of disordered eating and menstrual disturbance to be as high as 33% and 36%, respectively.[2,26] Additionally, it is well

established that the low estrogen state accompanying menstrual disturbance, is associated with low bone mineral density and increased risk of bone injury in female athletes.[1–3] We did not observe statistically significant differences in the burden of bone injury between the three latent classes, and the lack of variation in menstrual disturbance consequences by latent class may partially explain the lack of variability in bone injury outcomes observed. The high prevalence of menstrual disturbance warrants prevention and intervention efforts that target this population of NCAA DI female distance runners.

Overall, this study demonstrates high bone injury concerns in this population, and 57% (n= 121) of participants reported at least one sport-related bone injury over their running career. The vast majority of all bone injuries reported in this sample occurred during college. This is concerning for many reasons, including the additional psychological burden that injury may add to the already high-stress student-athlete lifestyle. The psychological response to injury may unmask or trigger mental health issues, partially when an athlete finds it especially challenging to cope with an injury.[27] Sport-related injury is associated with increased risk of depression and disordered eating, as well as isolation and general psychological distress among student-athletes.[28,29] These factors are not only worrisome from a public health standpoint that values the overall wellbeing of student-athletes, but also, because these same factors increase the risk of subsequent injury.[27]

In our study, the most commonly reported types of bone injuries included bone stress fracture (39.34%) and shin splints (10.1%). We reported a much higher prevalence of bone stress fractures as compared to one study of NCAA female Cross Country athletes from 22 teams over 5 years (2.3%, n=5).[30] This discrepancy may be due partially to differences in injury reporting. Kerr et al. (2016) relied on injury report by athletic training staff as part of the NCAA injury

surveillance program [30], as opposed to self-reported injuries by athletes as was done in our study. Our findings on bone stress fractures are more consistent with those reported by Tenforde et al. (2017), where the burden stress fractures was 34% among female college cross-country runners.[31] One study of female NCAA athletes reported recurrent stress fractures to be as high as 17.5% among cross country runners and 26% among outdoor track and field athletes.[32] This finding of recurrent stress fractures may help explain the high number of bone stress fractures, relative to other bone injuries, and raises important concerns for life course health and injury risk. Notably, bone stress fractures represent types of overuse injury caused by repetitive microtrauma to the bone from training load that exceeds necessary recovery time; however, these injuries are largely preventable and avoidable with proper rest and recovery.[33–35] Such a high burden of bone injury in this student-athlete population is a concerning public health issue, yet these injuries are largely preventable if athletes, coaches and medical personnel work together to balance the load of training and recovery.

The tremendous burden of bone injuries in this study is not entirely unexpected in this NCAA DI student-athlete population. These athletes may be reluctant to sit out of training and competition to allow for full recovery from lower intensity bone injuries, due to pressures from coaches and teammates. Further, a majority of distance runners compete in competitive seasons for cross country, indoor track and outdoor track seasons. Training demands may remain high after one competitive season in preparation for next; therefore, these athletes often have little recovery time during the year. Such a schedule allows very little time for the body to repair and recover fully from injury and perpetuates recurrent injury. [32] It is important that future research uses data collection measures including self-report of bone injuries to more fully capture all injuries in order to better understand incidence with respect to timing of competitive seasons. We

were unable to assess the timing of the bone injuries with respect to the onset of other RED-S consequences, and that this longitudinal understanding of the timing and onset of RED-S consequences should be a major area of future research

Strengths and Limitations

To our knowledge, this study is the first national, random sample of NCAA DI Cross Country runners to date. This is also the first epidemiologic study to assess the relationship between latent classes of RED-S health consequences and bone injury outcomes. This study has contributed to sport injury by expanding beyond the typical scope of bone stress injuries and reporting several types of bone injury outcomes in this collegiate female athlete population.

Despite notable strengths of this study, there are some important limitations to address. Due to the study sample size, we did not have sufficient power to look at the associations between bone fracture, bone break, and bone bruise outcomes and latent class membership. Further, all data was self-reported, and this may have contributed to biases in recall and reporting, particularly for bone injury outcomes that happened several years ago. Athletes may have mis-reported injury type and/or timing based on poor recall. It is possible that athletes did not report all past injuries, and, consequently, it is likely that the total injury count is underreported in this study. The cross-sectional nature of the survey limits our understanding of timing between RED-S consequences and bone injury outcomes. The majority of the RED-S consequences represent current or recent concerns; therefore, reverse causation is a potential limitation. Further, selection bias may be present, despite the use of random sampling, women who participated in the study may have those who had a personal interest in the study topics, and personal experiences with RED-S and/or a negative sport experience. This may have biased the

findings, if the final analytic sample included women with greater likelihood of having RED-S; thus, the study findings reflected women with greater health concern, and this may not represent the broader population of NCAA DI female cross country runners. Additionally, selection bias may have impacted the latent classes we observed; we did not observe a true healthy class of athletes, and it is possible that women who would have been assigned to a true healthy class did not participate in the survey. Alternatively, we may not have captured women that would have been assigned to a more severe RED-S class, as compared to LC 2 and LC3, if these women dropped out of the sport prior to this study or were selected for the study but uninterested in participating. It is possible that women who had more severe RED-S consequences experienced bone injury and/or other career-ending RED-S consequences, such as psychological health impacts, that removed them from sport, and therefore, they were not captured in our data.

Additionally, this study did not capture physical location of injuries, timing of injury with respect to competitive seasons, or duration of injury recovery. These are important areas of future inquiry to better inform prevention efforts against bone injury in particular locations of the body, to inform training protocols around high-risk time periods of injury, and better understand the burden of recovery time from injury. Future longitudinal studies are needed to better understand the temporal relationship between bone injury outcomes and latent classes of RED-S consequences.

Conclusion

This study examined the association between latent class membership and bone injury outcomes among NCAA DI female cross country runners. Overall, there was a very high burden of bone injury in this population, with the vast majority of injuries occurring during the college

years. The most common bone injuries reported represent types overuse injuries that are largely preventable with proper rest and recovery. Future longitudinal studies are necessary to capture incident bone injuries and better understand causal relationships between bone injury and latent classes of RED-S consequences.

Table 4.1. Latent Classes of RED-S Consequences (Without Bone Injury)

Low RED-S Consequence Class	Pr.	High RED-S Consequence Class	Pr.	Anxious, High RED-S Consequence Class	Pr.
Menstrual Dist	0.681	Cardiovascular	1	Anxiety	0.988
Hematologic	0.583	Hematologic	0.840	Menstrual Dist	0.692
Gastrointestinal	0.58	Menstrual Dist	0.787	Gastrointestinal	0.607
Immune	0.135	Anxiety	0.689	Hematologic	0.588
Anxiety	0.093	Gastrointestinal	0.662	Depression	0.383
Endocrine	0.044	Depression	0.469	Growth and Development	0.204
Growth and Development	0.086	Metabolic	0.258	Immune	0.182
Cardiovascular	0.019	Endocrine	0.177	Endocrine	0.129
Depression	0.015	Growth and Development	0.303	Cardiovascular	0.118
Metabolic	0	Immune	0.086	Metabolic	0.039

The conditional probabilities of each indicator variable for each class were categorized as low (grey), medium low (green), medium (blue), medium high (yellow), and high (red).

Table 4.2. Prevalence of Bone Injury Type

Injury Type	Ever		College	
	%	N (211)	%	N (211)
Any bone injury	57.35%	121	47.39%	100
Stress fracture	39.34%	83	34.60%	73
Bone fracture	1.90%	4	0.95%	2
Bone bruise	5.79%	7	2.84%	6
Shin splints	10.1%	23	9.00%	19
Bone break	2.37%	5	1.42%	3

Table 4.3. Chi-Square Test of Bone Injury (Ever) Distribution by Latent Class

Bone Injury, Ever	Low RED-S Consequence Class		High RED-S Consequence Class		Anxious, High Consequence Class		Overall test	Low vs High	Low vs Anxious	High vs Anxious
	%	N (80)	%	N (79)	%	N (52)	P-value	P-value	P-value	P-value
Any bone injury	54%	43	66.2%	52	56.0%	29	0.567	0.29	0.825	0.402
Stress fracture	38.9%	31	38.0%	30	40%	21	0.984	0.938	0.897	0.867
Shin splints	11.2%	9	15.6%	12	9.2%	5	0.756	0.588	0.731	0.456

Table 4.4. Chi-Square Test of Bone Injury During College Distribution by Latent Class

Bone Injury, College	Low RED-S Consequence Class		High RED-S Consequence Class		Anxious, High Consequence Class		Overall test	Low vs High	Low vs Anxious	High vs Anxious
	%	N (80)	%	N (79)	%	N (52)	P-value	P-value	P-value	P-value
Any bone injury	44%	35	50.1%	40	50.1%	26	0.773	0.619	0.519	0.997
Stress fracture	20.6%	16	33.7%	27	25%	13	0.455	0.225	0.538	0.469
Shin splints	23%	18	35%	28	23.9%	12	0.803	0.514	0.942	0.569

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Chapter 5

Conclusion

> "*The National Collegiate Athletic Association is a membership-driven organization dedicated to safeguarding the well-being of student-athlete and equipping them with the skills to succeed on the playing field, in the classroom and throughout life"* (NCAA, 2020).

This is the mission statement that the National Collegiate Athletic Association (NCAA) promises to uphold; however, serious questions have emerged in recent months Our study has the potential to contribute to how coaches, team leadership and other athletic staff communicate with athletes on the topic of eating disorders., challenging whether the NCAA has failed to uphold this mission. In October, the NCAA submitted an amicus brief petitioning the California State Supreme Court in response to three former student-athletes' claim that the "NCAA failed to protect them and others from sexual abuse and harassment they suffered at the hands of their NCAA track and field coach".[2] In it, the NCAA argued that they "no legal duty to protect NCAA student-athletes from predatory conduct" and further, "(NCAA) has no duty, imposed either by law or by contract, to protect student-athletes at NCAA member schools from sexual abuse".[2] This ongoing discussion regarding the health and safety of athletes warrants the need for objective, evidence-based information to inform future actions. This dissertation intended to provide evidence regarding the health and wellbeing of female NCAA distance runners, particularly concerning issues related to the Relative Energy Deficiency in Sport (RED-S

framework.[3] The future of female student-athlete success, and longevity in sport, relies upon accurate and unbiased research regarding the burden of physical and mental health concerns and support and resource needs in this population, and on the NCAA's commitment to its athletes beyond their success on the playing field.

Summary and Implications of Main Findings

This dissertation relied on primary data collection and utilized a mixed methods approach. First, we took an investigative approach to qualitatively capture the lived experiences of NCAA DI female cross country runners, and this informed the latter quantitative data collection. Secondly, we collected quantitative survey data to examine RED-S health consequences in the population of among NCAA DI female cross country runners.

Chapter 2 gave light to body image and diet norms in the sport of cross country, as well as coach-athlete relationships and power dynamics. The New York Times (NYT) story on Mary Cain and Nike broke during the process of writing this Chapter.[4] This story detailed the emotional abuse and physical turmoil Cain endured under Nike coach, Alberto Salazar. Cain detailed her struggles with dieting, amenorrhea, bone injury and suicidal ideation during her time with Nike's Oregon Project track team. Her story captured the experience of so many women in the sport and echoed women's personal experiences reported in this Chapter. The primary themes that emerged from twenty-nine interviews with current and former NCAA DI female distance runners included: 1) "the culture of running," with sub-themes that captured the *ideal "runner body*," the "*lighter is faster*" mentality, and the *event-type body identities,* and 2) "the coach-athlete relationship and power dynamic," with sub themes about *Recognition, Coaches Control*, and *Body and Food Comments*. These findings were reiterated by the thousands of

social media responses, of support and commiseration, following the rerelease of Mary Cain's story NYT story.

To our knowledge, this is the first qualitative study to examine factors contributing to the onset of disordered eating and body image disturbance in current or former NCAA DI female distance runners. Findings revealed that in the culture of female distance running, body-image norms and myths have persisted over decades, and the power dynamic between coach and athlete may contribute to an athlete's risk of disordered eating and body image disorders. These findings call for a greater focus on research regarding female athlete health, particularly among collegiate athletes. Our study provides preliminary evidence of important themes relevant to this population. Additional research, in larger samples, is needed to fully represent the diverse voices within this population. If confirmed in other studies, the issues surrounding eating and body image disorders, as well as abusive and emotionally manipulative coach-athlete relationships require robust and immediate attention by the NCAA to do more to safeguard female athlete health and safety.

Our findings from Chapter 2 informed the cohort development necessary for the analyses presented in Chapters 3 and 4. Due to the shortage of available data on NCAA female athletes, new data collection activities were necessary to address the research questions of interest for this dissertation. The overall lack of available data on this population is notable. While access to collegiate athlete populations is generally restricted, a greater investment in research on female collegiate athletes may affirm serious commitment to address physical and mental health needs in this population. A significant part of this study included cohort development and survey data collection that preceded the analysis phase. In absence of an already-available listing of NCAA D1 runners, we built a sampling frame by collecting available rosters from 350 NCAA DI teams

and cataloging individual athletes. We randomly sampled up to 10 women from each team, and individually searched the email contact information of each sampled athlete using publically available university databases. We built a Qualtrics survey capturing RED-S consequences, demographics, personal information, disordered eating and emotional health, incorporating questions about coaches and team environment informed by the preceding qualitative study.

The data collection phase took approximately 5 months, and after this phase, we completed latent class analysis to identify patterns of clustering of the ten RED-S health consequences. We reported a three-class model that highlights the high RED-S concern among our sample of 211 NCAA DI female distance runners. Importantly, two of the three latent classes (LC), LC2 and LC3, are characterized by complex sets of physical health concerns across most domains and LC3 is uniquely characterized by very high anxiety. LC1is the least severe class, characterized by moderate menstrual disturbance but lower across other RED-S domains. Importantly, all three classes share notable menstrual disturbance, hematologic and bone injury concern. Findings suggest that NCAA DI female distance runners are burdened by RED-S consequences, particularly anxiety, menstrual disturbance, as well as hematological and gastrointestinal concerns. This chapter provides important contributions to the literature on female athlete health and RED-S and is the first study look at how RED-S consequences cluster together. Screening for RED-S at pre-season physical examinations may prove beneficial in addressing and mitigating RED-S consequences in this population of NCAA DI female distance runners. This will require the commitment of athletic departments to increase financial resources for medical personnel to ensure timely treatment and continued monitoring of RED-S for the betterment of athlete health.

Chapter 4 examined the association between latent class membership and bone injury outcomes in our sample of 211 NCAA DI female distance runners. We performed latent class analysis, removing bone injury from the set of latent class indicator variables, as it was our distal outcome of interest. We fit a 3-class model, as informed by Chapter 3, and reported the following latent classes: Latent Class (LC) 1, the "Low RED-S Consequence Class", represents 38% (n=80) of participants and characterized as the least severe class, despite notable menstrual health concern; LC2, the "High RED-S Consequence Class", represents 37% (n=79) of participants and characterized by a complex set of physical health concerns across most domains, as well as medium to medium-high psychological concerns; LC3, the "Anxious, High RED-S Consequence Class", represents 25% (n=52) of participants and characterized by high anxiety along with a complex set of physical health concerns across most domains.

Our findings revealed a very high burden of bone injury in this population of NCAA D1 female Cross-Country runners, with the vast majority of injuries occurring during college (47%). The most common bone injuries reported, stress fractures and shin splints, represent types overuse injuries that are largely preventable with proper attention to rest and recovery. We used Chi-Square analyses to report the associations between latent class membership and bone injury outcomes (bone injury, bone stress fracture, and shin splints) ever, and during college. We observed no statistically significant differences in the burden of bone injury between the three latent classes. This finding may be partially explained by the high burden of menstrual disturbance in all three latent classes; however, future longitudinal studies are needed to better understand causal relationships between features of RED-S and bone injury outcomes.

Strengths and Limitations

While this dissertation offers many novel contributions to female athlete health and RED-S research, there are important limitations that warrant discussion. First, the qualitative study sample was limited to interviews with 29 current and former NCAA DI cross country runners, and results may not represent the majority of DI female cross country runners. Similarly, selection bias is may be present, given that we undertook a word of mouth sampling strategy, and women with a strong interest in the study topic may have been more likely to participate. If this selection bias is present, the findings may not be representative of the broader population of NCAA DI cross country runners, and only represent the women who had a strong interest in participating in this study.

Further, although the qualitative sample was geographically diverse, representing the experience of women from multiple regions and NCAA conferences, it does not include notable racial, ethnic and socioeconomic diversity, limiting our understanding to mostly White, upper middle-class athletes. We understand that qualitative research has potential biases in interviewer influence and social desirability effects. Further, we used two different modes to complete the interviews with subjects, in-person interviews and video conferencing interviews. Using multiple modes may have contributed to bias if participants were more comfortable sharing their personal experiences in one mode more than the alternate option. Lastly, despite precautions taken to ensure a rigorous coding approach, it is important to note that qualitative coding and analysis typically allows for more human error and partiality, as compared to quantitative methods.[5]

The data in Chapters 3 and 4 is subject to limitations and biases inherent to online survey data collection, namely reporting and selection biases. Our final sample size limited our ability to perform additional analyses, due to a lack of power that this sample allowed us. Further, the self-reported nature of the survey data collection, particularly for medical and health related

information, is subject to both recall and social desirability bias. Further, if athletes with a personal connection to the study topic were more likely to participate, this there is a chance that response bias is present. Further, a major limitation that warrants improvement in future research, was the measurement of particular RED-S variables that are challenging to capture via self-report. Particularly, the measurement of endocrine and metabolic consequences are of particular concern. It will be vital that measures for self-reported RED-S consequences are improved in the near future, particularly those that are not as "obvious" or identifiable to athletes, such as menstrual disturbance and bone injury. In Chapter 4, athletes may have mis-reported injury type and/or timing, due to poor recall. Additionally, it is possible that athletes did not report all past injuries, and it is likely that the total injury count is underreported. Lastly, and very importantly, this study was cross sectional, and this greatly limits our understanding of the timing and ordering of RED-S consequences, and this is an exciting and novel research area for future inquiry.

Despite the noted limitations, this dissertation has several strengths. First, this dissertation used a mixed methods approach, allowing for an inductive approach to the research. This dissertation relied on primary data collection, which allowed us to contribute novel data to the field of female athlete health research. Further, it allowed us to collect data in a rigorous way; for the qualitative data analysis process, employing double coding, and using random sampling for the quantitative study.

For Chapters 3 and 4, the quantitative data collection had many strengths, most notably the randomized sampling design. To our knowledge, this is the first national, random sample of any NCAA sport to date, and subsequently, the first randomly sampled, epidemiologic study to assess RED-S health consequences. We also incorporated the qualitative findings into the survey

component, and this allowed us to have a more robust survey that updated the current available data on female athlete health and wellbeing, particularly around RED-S. Chapter 4 is the first epidemiologic study to assess the relationship between latent classes of RED-S health consequences and bone injury outcomes. Additionally, this study has contributed to sport injury by reporting several types of bone injury outcomes in this collegiate female athlete population.

Future Research

The primary data collection undertaken in this dissertation serves as a perfect jumping off point for future research. While we present qualitative evidence for the impact of coaches on the health and wellbeing of college athletes, that study was just one step towards capturing the power dynamics at play in elite and intercollegiate athletics. Chapter 2 found that power dynamics between coach and athlete may contribute to female athlete's risk of disordered eating and body image disturbance, and future translational and intervention research should work with coaches to address this pressing issue. This will be an important next step towards ensuring coaches are trained on the topics of RED-S, eating disorders, and the impacts off athlete-coach relational dynamics.

In creating a cohort of NCAA cross country runners, we have laid the groundwork to collect longitudinal data, and follow women over time to examine how the onset of RED-S progresses over the course of the collegiate career and beyond. The temporal relationship of RED-S consequences has never been examined, beyond the relationship between low EA, menstrual disturbance and bone health in the literature on the Female Athlete Triad.[6–9] The other eight health consequences of the RED-S framework have not been examined longitudinally in any population of athletes, and this is a major criticism of the RED-S framework.[10] Authors of the Female Athlete Triad published a statement to pushback against the RED-S model and

argued that RED-S was "insufficiently supported by scientific research," and a major concern was the oversimplified model that portrays the RED-S domains as independent effects.[10] Future longitudinal research is needed to address the timing and onset of RED-S consequences.

Further longitudinal studies can help address the limited scientific understanding of the effects of low EA and menstrual disturbance in female athletes, and its' future impact on fertility and reproductive health.[11–13] Concurrent with ongoing data collection, there must be improvement in the accuracy of self-reported RES-S measures, particularly for endocrine and metabolic health. This will take collaboration with clinicians and specialists in endocrine and metabolic health, to create survey measures that are more sensitive to capturing these domains of RED-S. Overall, longitudinal research is vital to our understanding of the chronic impacts of RED-S on the health of female athletes over the lifespan. This knowledge will help reinforce why prevention and early intervention of RED-S is imperative for acute health and performance, as well as life course impacts of RED-S.

Public Health Significance

This dissertation has built upon the decades literature on the Female Athlete Triad that established the three interrelated syndromes of low EA, menstrual disturbance and low bone mineral density in female athletes. [10,14] Additionally, this dissertation draws on the newer RED-S framework that includes ten physical health outcomes hypothesized to result from low EA.[3] This dissertation drew upon these existing bodies of work, while also calling on the voices of current athletes. Our qualitative findings draw attention to harmful sport body-image ideals and coach-athlete power dynamics, and quantitative findings highlight the significant burden of RED-S consequences and bone injury in this population.

The findings in Chapter 2 highlighted cultural and environmental risk factors for disordered eating and Female Athlete Triad /RED-S in the sport of long distance running. The prevalence of disordered eating among female runners has been reported to be twice as high as their non-athlete peers, ranging from 33% to 50% versus 8% to 17%, respectively.[8,15,16] The majority of research on risk factors for the disordered eating has focused largely on individual-level behavioral characteristics, as well as biological or physiological characteristics in small samples of athletes.[17–20] Chapter 2 revealed that the culture of distance running encouraged and normalized restrictive eating in pursuit of both ideal aesthetic with the promise of improved performance, and further, emotional manipulation from college coaches that was a source of significant psychological distress. These findings revealed aspects of the sport environment that contribute to adverse health consequences among collegiate runners. From a prevention standpoint, a significant opportunity presents for the NCAA and athletic departments implement routine screening programs to identify disordered eating in this high-risk population, before it progresses to more serious presentations.

The results from Chapter 3 highlight the high burden of RED-S consequences, particularly menstrual disturbance, anxiety, as well as hematologic and gastrointestinal concerns. Results of the latent class analysis showed that all of the classes were burdened by high menstrual disturbance, which may be a marker of low energy availability, with or without disordered eating.[3] From a clinical standpoint, athletes assigned to the "High RED-S Consequence Class" may require more timely care, particularly given the significant cardiovascular concerns in this class. However, athletes in the "Anxious, High RED-S Consequence Class" warrant psychological healthcare that is also an urgent concern. Based on the findings of this study, this population of athletes has a high burden of physical and

psychological health complaints. More research is needed to replicate these findings on a larger sample of athletes, perhaps including athletes from other sports. Further, future work should evaluate the current physical and/or mental health care that athletes have access to, to understand any potential gaps in available support services in this population. Evidence suggests that both screening and later-stage intervention strategies can be beneficial in mitigating RED-S consequences.[21]

The results of Chapter 4 highlight the high burden of bone injury outcomes in this population, with the majority of injuries occurring during the college years. Sport-related injury is known to be associated with an increased risk of depression and disordered eating, as well as isolation and general psychological distress among student-athletes.[22] From a public health standpoint, the mental health of college students is a notable concern. College students are already at an increased risk of developing mental health disorders,[23] and college student athletes report lower use of mental health services compared to non-athlete peers.[24] Bone stress fractures, a type of overuse injury, were the most common bone injuries in this population. From a public heath perspective, such a high burden of bone injury in this student-athlete population is concerning, yet these injuries are largely preventable if athletes, coaches and medical personnel work together to balance the load of training and recovery.

Conclusion

There is a need for need for additional high quality, unbiased research in the area of female athlete health, particularly with respect establishing an understanding the longitudinal timing and onset of RED-S in female athletes. Following in the footsteps of Mary Cain, and looking beyond the research community, there must be continued conversations on informal

platforms, including op-eds, books and social media, that highlight female athletes' stories and calls for change and reform in the culture of college sport. These findings aim to serve both clinical and translational importance; informing medical and sport professionals on the variations in RED-S presentations and inform public health screening and intervention for RED-S and body image and eating disorders. Taken together, the results of this dissertation contribute novel data and findings to our understanding of RED-S in collegiate female athletes. Our findings bring attention to disordered eating and the significant burden of RED-S among NCAA DI female distance runners. This dissertation calls for more research on disordered eating and RED-S among collegiate athletes that may inform needed changes, and prevention and intervention programs, within the NCAA and athletic departments.

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APPENDICES

Semi-Structured Qualitative Interview Guide Chapter 2

Warm-up

1. What got you interested in running?

2. When did you start?
    a. How early (age) did you start competing/training at a serious/high level?
        i. Probe: for frequency/intensity of training? was it high school/earlier?
    b. How many years have you/did you compete in college?
        i. Probe: Why?
3. Family life? Supportive of running?
    a. Parents, sister/brother runners? Athletes?

4. Relationship with coaches?
    a. Before college? College and pro coaches?
    b. What was their personality like? Your personality?
    c. What would your coaches have said/say about you now?

Body image and Food Intake

5. Did you ever learn about "proper" nutrition for athletes?
    a. Probe: From who? mom, coach, friend, dietitian?
        i. Read about it? Etc.?

6. What was your relationship with food/body image like throughout your life?
    a. Probe: positive/negative?

TRIAD onset and DE/ED

7. Do you have any types of dietary restrictions or food allergies?
    a. Probe: dairy, gluten, etc.? How long ago did you find out? Do you avoid these foods?

8. What types of food rules do you follow now? or have followed in the past?
    a. Probe: vegan/vegetarian/paleo/etc.?

9. Some people use MyFitnessPal, keep logs, etc. to track food…some people don't track/monitor at all… do you actively monitor your food intake?
    a. Probe: weigh/measure food, MyFitnessPal, count macros?

i. When did you start? Why? How did you learn about it?

10. What types of messages have you received from coaches/teammates about body size/weight? about food and dieting?
    a. Before college? During?
    b. Follow ups:
        i. Frequency?
        ii. How did it affect you, if at all?
    c. Probe: positive/negative?

11. Do you notice any differences in the way your teammates eat compared to the way you eat? Non-teammate friends compared to you?
        i. Probe: More or less frequently? Larger or smaller portions? Specifically avoid sugar? Gluten?
            1. What do you think about this? How does that make you feel?

12. Do you get the sense that many female athletes/runners have disordered eating and/or poor body image?
    a. Why do you think this? Why is this the culture? When did you first notice?

Menstrual Disturbance

13. What age did you get your first period?

14. How did you feel when you got your first period? Circumstances?
        i. Probe: Proud? Shame/fear? Etc?
15. Did you know what a period meant?
    a. Did did you learn about puberty/development? At home? School?
    b. Sex ed and anatomy?
        i. Family? School? Other?

16. Have you ever missed periods for reasons other than birth control/pregnancy? How did you react?
    a. Probe: Did you tell anyone? How old were you?
    b. If told Physician/trainer follow up: What did your physician/trainers tell you about missing periods?
        i. How did you feel about this?

17. What type of birth control have you used in the past? How long and when?
    a. How did BC make you feel?
    b. Did it impact performance? Side effects?
        i. What were they? How often? How did it make you feel?

18. What was the team culture around talking about periods? Birth control? Did teammates talk about it?
        i. Probe: If no, why do you think that was?

ii. Probe: If yes, what kinds of comments did friends/teammates make about missing periods?
    1. Probe: positive/negative?

Injury/Health

19. Have you experienced sport-related injuries? Stress Fractures?
    a. If yes, what were they?
    b. When, how long, how painful?
        i. Probe: If yes, how did you react emotionally?
            a. Probe: how did you cope?
        ii. Probe: If yes, did your food intake change while injured?
            1. Probe: How? In what ways did it change? Why did it change?

20. What other health issues did you/have you faced since you started training/competing at a high level?
    a. Probe: Infertility, Night sweats, Gastrointestinal upset, mood/irritability, Cardiovascular (low/high heart rate), low sex drive, other?
    b. Probe cognition: Were there times when you felt like you were "losing your words?" Times when your thoughts were slower/memory worse than usual? Examples?
        i. When? How long? How did this make you feel?

21. Have you experienced anxious or depressive thoughts/feelings? What kinds of thoughts/feelings?
        i. Probe: If yes, when did this start? Duration? Intensity? Did you address it at the time?
            1. Did you tell anyone? Who? Why did you tell them?

    b. Follow up: How have the anxious or depressive thoughts/feelings changed over the years?
        i. Probe: Change related to starting medication, therapy, changing diet, living situation, etc.?

Weight Suppression

22. How did your weight change throughout your time in high school? College? Beyond?

23. When were you at your highest weight at your current height?
    a. How did you **feel** at this weight?
        i. Probe: Energy levels, mood, recovery, body image, sport performance?

24. When were you at your lowest weight at current height?
    a. How did you feel at this weight?
        i. Probe: Energy levels, mood, body image, sport performance?

    b. Follow up: Do you have clear memories from this time (at your lowest weight)?

i. Probe: Of school/academics? Social life? Mood and happiness? Fatigue? Etc.

25. Were you motivated to achieve this lower weight for a specific reason?
    a. Probe: Why?
        i. Increased performance, to look leaner/thinner/smaller, for praise, to be more attractive, to "look" more like an athlete, to make someone else happy, to make yourself happy?

26. To what extent did you engage in social life (parties, fun team outings, sports events, etc.) at your lowest weight compared to higher weights?
    a. Probe: How often? What activities? With teammates or other friends? On
        i. Probe: How does this make you feel?
    b. Romantic relationships? Dating? At lowest vs. highest weight?
        i. Probe: Why do you think this was?
        ii. Probe: How is it different? In what ways? How do you feel about this?

27. What types of comments did you receive about your body/shape/appearance at your highest weight? At your lowest weight?
    a. Probe: Positive/negative comments? Did you have a positive/negative reaction? How often?
    b. Probe: Did you agree?
    c. Probe: From whom (friends/family/coaches/teammates/significant other)?

28. Are you currently purposefully trying to lose weight?
    a. Probe: Why? What is the motivation? What diet are you following? Exercise routine?

Help-Seeking and Care

29. Have you ever gone to see a nutritionist? A therapist/psychologist?
    a. Probe: When did you start? Why? What motivated you?
    b. Probe: For how long? How frequently?
        i. Positive/negative experience?
    c. Probe: If yes, was this a team/AD related nutritionist/therapist? Off campus? Other?
        i. For how long? How frequently? Positive/negative experience?

Conclude

30. What advice would you tell other girls/women new to competing in running about eating habits and overall health?

Survey Chapter 3 and 4: The FASHT Cohort

Qa Name (First and Last)

_____

Q607 Name (First and Last)

_____

Q2 Date of Birth (DD/MM/YYYY)

_____

Qb Address (temporary)

_____

_____

Qc Phone Number (xxx-xxx-xxxx)

_____

Qd Preferred e-mail

_____

Q234 Permanent Address

_____

_____

_____

_____

_____

Qe **Contact proxy**

Please provide the name of a parent, other family member, or close friend that we can contact on your behalf, in the case that we can not reach you in the future.

We will not share your survey answers with this proxy, and all of your survey answers will remain anonymous.

○ Proxy Name (first and last) (3) _____

○ Proxy phone number (4) _____

○ Proxy e-mail (5) _____

Q1
If possible, please have current and/or former training logs, food logs, and medical records on hand for reference during the survey.

Q3 Which term do you use to describe your sexual identity? (Select all that apply)

☐ Straight/Heterosexual (1)

☐ Bisexual (2)

☐ Gay (3)

☐ Lesbian (4)

☐ Questioning (5)

☐ Asexual (6)

☐ Pansexual (7)

☐ Other (8) _____

Q4 Which term do you use to describe your gender identity? (Select all that apply)

☐ Woman (1)

☐ Transgender (2)

☐ Transexual (3)

☐ Queer (4)

☐ Questioning (5)

☐ Intersex (6)

☐ Other (7) _____

Q5 How do you usually describe your race? (Select all that apply)

- ☐ White (1)
- ☐ Black or African American (2)
- ☐ Asian or Asian American (3)
- ☐ American Indian (4)
- ☐ Native Hawaiian or Pacific Islander (5)
- ☐ Other (6) _____

Q6 How do you usually describe your ethnicity?

- ○ Hispanic or Latino (1)
- ○ Not Hispanic or Latino (2)

Q7 Which of the following best describes your family's **current** socioeconomic status?

- ○ Well to do (1)
- ○ Comfortable (2)
- ○ Had enough to get by but not many "extras" (3)
- ○ Very poor, not enough to get by (4)

Q8 Mother's highest educational level

- ○ Less than high school (1)
- ○ High school (2)
- ○ Some college (3)
- ○ College (4)
- ○ Post-graduate degree (5)

Q9 Father's highest educational level

- ○ Less than high school (1)
- ○ High school (2)
- ○ Some college (3)
- ○ College (4)
- ○ Post-graduate degree (5)

Q10 Did your family own a car when you were a child or teenager?

- ○ Yes (1)
- ○ No (2)

Q11
Did your family ever receive public assistance when you were a child or teenager?

- ○ Yes (1)
- ○ No (2)

Q12 Did your family ever have difficulty paying for food or rent or making ends meet when you were a child or teenager?

- ○ Yes (1)
- ○ No (2)

Q278 Have you transferred universities at any point during college (including 5th year undergrad, graduate, or professional school)?

- ○ Yes (1)
- ○ No (3)

Q13 Name of the university you are **currently** attending:

▼ Abilene Christian univ. (4) ... Wofford College (240)

Q235 What athletic conference does your current team compete in? (i.e. Big Ten, Pacific-12, Mountain West)

▼ America East Cross Country Championships (4) ... Western Athletic Conference (36)

Q14 What is your current year in school?

▼ 1st year undergraduate (1) ... Graduate or professional student (6)

Q15 Undergraduate Academic Major

_____

Q16 Did you receive an athletics scholarship of any kind during college?

- Yes (1)
- No (2)

Q17 High School GPA:

0 1 1 2 2 3 3 4 4 5

GPA ()

Q469 GPA out of:

- 4.0 (1)
- 5.0 (2)
- Other (3) _____

Q260 College GPA and scale? (i.e. 3.5 out of 4.0)

0 1 1 2 2 3 3 4 4 5

GPA ()

Q471 GPA out of:

- 4.0 (1)
- 5.0 (2)
- Other (3) _____

Q452 **We will now ask you about your personal history with running, as well as your training history.**

Q19 How old were you when you started competing (running in local races, recreational club/team, school team, summer program) in running?

	0 2 5 7 10 12 14 17 19 22 24
Age ()	

Q279 Do you specialize in running/consider running to be your primary sport?

- Yes (1)
- No (2)
- Not sure (3)

Q262 How old were you when you started specializing in running (intense training in running, while excluding other sports)?

	0 2 5 7 10 12 14 17 19 22 24
Age ()	

Q21 Years competed in Cross Country, including redshirt* seasons? (Select all that apply)

**What a "redshirt" season refers to is a year in which a student-athlete does not compete at all against outside competition*

- ☐ Middle school or earlier (1)
- ☐ Freshman High School (2)
- ☐ Sophomore High School (3)
- ☐ Junior High School (4)
- ☐ Senior High School (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional school (11)

Q571 Highest accomplishment in collegiate Cross Country (to date):

- ○ Practice squad (1)
- ○ Travel team (2)
- ○ All-conference (3)
- ○ All-region (4)
- ○ All-American (5)

Q22 Did you redshirt any season of Cross Country during college?

- ○ Yes (1)
- ○ No (2)

Q22a If yes, when? (Select all that apply)

- ☐ 1st year undergraduate (1)
- ☐ 2nd year undergraduate (2)
- ☐ 3rd year undergraduate (3)
- ☐ 4th year undergraduate (4)
- ☐ 5th year or more undergraduate (5)
- ☐ Graduate or professional school (6)

Q23 Years competed in Indoor Track (including red-shirt seasons)? (Select all that apply)

- ☐ Middle School or earlier (1)
- ☐ Freshman High School (2)
- ☐ Sophomore High School (3)
- ☐ Senior High School (4)
- ☐ 1st year undergraduate (5)
- ☐ 2nd year undergraduate (6)
- ☐ 3rd year undergraduate (7)
- ☐ 4th year undergraduate (8)
- ☐ 5th year or more undergraduate (9)
- ☐ Graduate or professional school (10)
- ☐ None (12)

Q572 Highest accomplishment in collegiate indoor track (to date):

- ○ Practice squad (1)
- ○ Travel team (4)
- ○ All-conference (5)
- ○ All-region (6)
- ○ All-American (7)

Q24 Did you redshirt any season of Indoor Track during college?

- ○ Yes (1)
- ○ No (2)

Q24a If yes, when? (Select all that apply)

- ☐ 1st year undergraduate (1)
- ☐ 2nd year undergraduate (2)
- ☐ 3rd year undergraduate (3)
- ☐ 4th year undergraduate (4)
- ☐ 5th year or more undergraduate (5)
- ☐ Graduate or professional school (6)

Q25 Years competed in Outdoor Track (including red-shirt seasons)? (Select all that apply)

- ☐ Middle school or earlier (1)
- ☐ Freshman High School (2)
- ☐ Sophomore High School (3)
- ☐ Junior High School (4)
- ☐ Senior High School (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional school (11)
- ☐ None (12)

Q573 Highest accomplishment in collegiate outdoor track (to date):

- ○ Practice squad (1)
- ○ Travel team (4)
- ○ All-conference (5)
- ○ All-region (6)
- ○ All-American (7)

Q26 Did you redshirt any season of Outdoor Track during college?

- ○ Yes (1)
- ○ No (2)

Q26a What year(s) did you red shirt? (Select all that apply)

- ☐ 1st year undergraduate (1)
- ☐ 2nd year undergraduate (2)
- ☐ 3rd year undergraduate (3)
- ☐ 4th year undergraduate (4)
- ☐ 5th year undergraduate (5)
- ☐ Graduate or professional school (6)
- ☐ Post-graduate professional or semi-professional (7)

Q147 - Q151
Please indicate your training load in high school and college.

	High School (1)	College (2)
Average miles run per week during Cross Country season (1)		
Average miles run per week during outdoor track season (2)		
Average hours of cross training per week (lifting, biking, etc) during Cross Country season (3)		
Average hours of cross training per week (lifting, biking, etc) during track season (4)		
Average number of rest days per week (NO running/ cross training, only yoga/mobility/stretching) in season (Cross Country and Track) (5)		

Q451 **We will now ask you to reflect on the times that someone may have commented on your body weight, food intake, or shape, both before and during college.**

Q591 **Before college**, did a parent make a comment **criticizing** your body weight, food intake, or shape?

- ○ Yes (1)
- ○ No (2)

Q595 If yes, when? (Select all that apply)

- ☐ Middle School or earlier (1)
- ☐ Freshman High School (2)
- ☐ Sophomore High School (3)
- ☐ Junior High School (4)
- ☐ Senior High School (5)

Q592 **Before college**, did a parent make a positive comment about your body weight, food intake, or shape?

- ○ Yes (1)
- ○ No (2)

Q596 If yes, when? (Select all that apply)

- ☐ Middle School or earlier (1)
- ☐ Freshman High School (2)
- ☐ Sophomore High School (3)
- ☐ Junior High School (4)
- ☐ Senior High School (5)

Q593 During college, did a parent make a comment criticizing your body weight, food intake, or shape?

- ○ Yes (1)
- ○ No (2)

Q597 If yes, when? (Select all that apply)

- ☐ Middle School or earlier (1)
- ☐ Freshman High School (2)
- ☐ Sophomore High School (3)
- ☐ Junior High School (4)
- ☐ Senior High School (5)

Q594 During college, did a parent make a positive comment about your body weight, food intake, or shape?

- ○ Yes (1)
- ○ No (2)

Q598 If yes, when? (Select all that apply)

- ☐ Middle School or earlier (1)
- ☐ Freshman High School (2)
- ☐ Sophomore High School (3)
- ☐ Junior High School (4)
- ☐ Senior High School (5)

Q563 **Before college**, did a coach make a comment **criticizing** your body weight, food intake, or shape?

- ○ Yes (1)
- ○ No (2)

Q580 If yes, when? (Select all that apply)

- ☐ Middle School or earlier (1)
- ☐ Freshman High School (2)
- ☐ Sophomore High School (3)
- ☐ Junior High School (4)
- ☐ Senior High School (5)

Q28 **Before college**, did a coach make a **positive** comment about your body weight, food intake, or shape?

- ○ Yes (1)
- ○ No (2)

Q28a If yes, when? (Select all that apply)

- ☐ Middle School or earlier (1)
- ☐ Freshman High School (2)
- ☐ Sophomore High School (3)
- ☐ Junior High School (4)
- ☐ Senior High School (5)

Q237 During college, did a coach make a comment criticizing your body weight, food intake, or shape?

- ○ Yes (1)
- ○ No (2)

Q238 If yes, when? (Select all that apply)

- ☐ Freshman Year (1)
- ☐ Sophomore Year (2)
- ☐ Junior Year (3)
- ☐ Senior Year (4)
- ☐ 5th year or or graduate/professional school (5)

Q239 During college, did a coach make a positive comment about your body weight, food intake, or shape?

- ○ Yes (1)
- ○ No (2)

Q240 If yes, when? (Select all that apply)

- ☐ Freshman Year (1)
- ☐ Sophomore Year (2)
- ☐ Junior Year (3)
- ☐ Senior Year (4)
- ☐ 5th year or graduate/professional school (5)

Q283
Please indicate your level of agreement with the following statements about your **college** head Cross Country coach.

(If your head Cross Country coach changed throughout college, answer for the coach you spent the most time with)

Q31 My head Cross Country coach...

Has made a critical comment about another teammate or competitors weight or body shape

- ○ Yes (1)
- ○ No (2)

Q32 Has made a positive comment about another teammate or competitors weight or body shape

- ○ Yes (1)
- ○ No (2)

Q33 Makes negative comments about me in front of others (related to things other than weight or body shape)

- Yes (1)
- No (2)

Q37 Treats all members of the team equally

- Strongly Agree (1)
- Agree (2)
- Neutral (3)
- Somewhat disagree (4)
- Strongly disagree (5)

Q38 Cares about my physical well-being

- Strongly Agree (1)
- Agree (2)
- Neutral (3)
- Somewhat disagree (4)
- Strongly disagree (5)

Q39 Cares about my mental well-being

- Strongly Agree (1)
- Agree (2)
- Neutral (3)
- Somewhat disagree (4)
- Strongly disagree (5)

Q599 Comments

_____

_____

Description 2 Please indicate your level of agreement with the following statements about your **college Cross Country teammates.**

(If you transferred or changed teams throughout college, answer for the teammates you spent the most time with)

Q40 **My teammates…**

Have made critical comments about my weight or body shape

- Yes (1)
- No (2)

Q41 Have made positive comments about my weight or body shape

- Yes (1)
- No (2)

Q42 Make critical comments about their own weight or body shape

- Yes (1)
- No (2)

Q43 Make positive comments about their own weight or body shape

- Yes (1)
- No (2)

Q44 Have made critical comments about another teammate or competitors weight or body shape

- Yes (1)
- No (2)

Q45 Have made positive comments about another teammate or competitors weight or body shape

- Yes (1)
- No (2)

Q46 Make negative comments about me in front of others (related to things other than weight or body shape)

- Yes (1)
- No (2)

Q47 Care about my physical well-being

- Strongly Agree (1)
- Agree (2)
- Somewhat disagree (3)
- Strongly disagree (4)

Q48 Care about my mental well-being

- Strongly Agree (1)
- Agree (2)
- Somewhat disagree (3)
- Strongly disagree (4)

Q600 Comments

_____

_____

Q301 Do you participate in track, in addition to cross country?

○ Yes (1)

○ No (2)

Q641
Please indicate your level of agreement with the following statements about your **college** head track coach.

(If your head track coach changed throughout college, answer for the coach you spent the most time with)

Q642 My head track coach...

Has made a critical comment about another teammate or competitors weight or body shape

○ Yes (1)

○ No (2)

Q643 Has made a positive comment about another teammate or competitors weight or body shape

○ Yes (1)

○ No (2)

Q644 Makes negative comments about me in front of others (related to things other than weight or body shape)

○ Yes (1)

○ No (2)

Q645 Treats all members of the team equally

- ○ Strongly Agree (1)
- ○ Agree (2)
- ○ Neutral (3)
- ○ Somewhat disagree (4)
- ○ Strongly disagree (5)

Q646 Cares about my physical well-being

- ○ Strongly Agree (1)
- ○ Agree (2)
- ○ Neutral (3)
- ○ Somewhat disagree (4)
- ○ Strongly disagree (5)

Q647 Cares about my mental well-being

- ○ Strongly Agree (1)
- ○ Agree (2)
- ○ Neutral (3)
- ○ Somewhat disagree (4)
- ○ Strongly disagree (5)

Q601 Comments

_____

_____

_____

Q648 Please indicate your level of agreement with the following statements about your **college track teammates.**

(If you transferred or changed teams throughout college, answer for the teammates you spent the most time with)

Q649 **My track teammates…**

Have made critical comments about my weight or body shape

○ Yes (1)

○ No (2)

Q650 Have made positive comments about my weight or body shape

○ Yes (1)

○ No (2)

Q651 Make critical comments about their own weight or body shape

○ Yes (1)

○ No (2)

Q652 Make positive comments about their own weight or body shape

○ Yes (1)

○ No (2)

Q653 Have made critical comments about another teammate or competitors weight or body shape

○ Yes (1)

○ No (2)

Q654 Have made positive comments about another teammate or competitors weight or body shape

○ Yes (1)

○ No (2)

Q655 Make negative comments about me in front of others (related to things other than weight or body shape)

- ○ Yes (1)
- ○ No (2)

Q656 Care about my physical well-being

- ○ Strongly Agree (1)
- ○ Agree (2)
- ○ Somewhat disagree (3)
- ○ Strongly disagree (4)

Q657 Care about my mental well-being

- ○ Strongly Agree (1)
- ○ Agree (2)
- ○ Somewhat disagree (3)
- ○ Strongly disagree (4)

Q602 Comments

_____

_____

_____

Q264 **We will now ask you about your injury history.**

Q580 Have the majority of your college teammates experienced an injury at some point?

- ○ Yes (1)
- ○ No (2)

Q51 What percentage (%) of your college teammates have experienced a sport related injury?

0 10 20 30 40 50 60 70 80 90 100

% ()	

Q50
Have you had absences from training or participation in competitions during high school, college due to a sport related injury?

- ○ Yes, one or more times (1)
- ○ No, not at all (5)

Q938 If yes, what kind of injury was injury number ${lm://CurrentLoopNumber}:

- ○ Bone (i.e. shin splints, stress-fracture, fracture, bone bruise) (1)
- ○ Muscle (2)
- ○ Ligament (3)
- ○ Tendon (4)
- ○ Other (5) _____
- ○ I have never had a sports related injury (6)

Q939 If bone, which type of injury:

- ○ Shin splints (1)
- ○ Bone bruise (2)
- ○ Stress fracture (3)
- ○ Fracture (5)
- ○ Broken bone (4)
- ○ Other (6) _____

Q940 If bone, which bone(s)?

- ☐ calcaneus (1)
- ☐ capitate bone (4)
- ☐ cervical vertebrae (5)
- ☐ coccyx (6)
- ☐ cuboid bone (7)
- ☐ distal phalanges (8)
- ☐ distal phalanges (9)
- ☐ femur (10)
- ☐ fibula (11)
- ☐ hamate bone (12)
- ☐ humerus (13)
- ☐ intermediate phalanges (14)
- ☐ intermediate cuneiform bone (15)
- ☐ lateral cuneiform bone (16)
- ☐ lumbar vertebrae (17)
- ☐ lunate bone (18)
- ☐ medial cuneiform bone (19)
- ☐ metatarsal bone (20)
- ☐ navicular bone (21)
- ☐ metacarpal bones (22)
- ☐ ossa coxae (23)
- ☐ patella (24)
- ☐ pisiform bone (25)
- ☐ proximal phalanges (26)
- ☐ proximal phalanges (27)
- ☐ radius (28)
- ☐ ribs (29)
- ☐ sacrum (30)
- ☐ scaphoid bone (31)
- ☐ sternum (32)

- ☐ talus (33)
- ☐ thoracic vertebrae (34)
- ☐ tibia (35)
- ☐ triquetral bone (36)
- ☐ trapezium (37)
- ☐ trapezoid bone (38)
- ☐ ulna (39)
- ☐ Other (40)
- ☐ Not sure (41)

Q941 If muscle, which muscle(s)?

- ☐ Abdominals (1)
- ☐ Biceps (4)
- ☐ Deltoid (5)
- ☐ Erector Spinae (6)
- ☐ Gastrocnemius & Soleus (7)
- ☐ Gluteus Maximus (8)
- ☐ Hamstrings (9)
- ☐ Latissiumus Dorsi & Rhomboids (10)
- ☐ Obliques (11)
- ☐ Pectoralis (12)
- ☐ Quadriceps (13)
- ☐ Trapezius (14)
- ☐ Triceps (15)
- ☐ Other (16)
- ☐ Not sure (17)

Q942 If ligament, which ligament(s)?

- ☐ Anterior cruciate ligament (ACL) (4)
- ☐ Posterior cruciate ligament (PCL) (7)
- ☐ Medial cruciate ligament (MCL) (8)
- ☐ Lateral collateral ligament (LCL) (9)
- ☐ Other (10)
- ☐ Not sure (11)

Q943 If tendon, which tendon(s)?

- ☐ Achilles tendon (27)
- ☐ Adductor longus, brevis and magnus tendons (4)
- ☐ Biceps tendons (7)
- ☐ Brachioradialis tendons (8)
- ☐ Deltoid tendons (9)
- ☐ Erector spinae tendons (10)
- ☐ External oblique tendons (11)
- ☐ Iliopsoas tendons (12)
- ☐ Latissimus dorsi tendons (13)
- ☐ Obturator internus tendons (14)
- ☐ Gluteus maximus (15)
- ☐ Gluteus medius tendons (16)
- ☐ Infraspinatus tendons (17)
- ☐ Patellar tendon (18)
- ☐ Subscapularis tendons (19)
- ☐ Supinator tendons (20)
- ☐ Supraspinatus tendons (21)
- ☐ Sartorius tendons (22)
- ☐ Teres minor tendons (23)
- ☐ Transversus abdominis tendons (24)
- ☐ Triceps tendons (25)
- ☐ Other (26)
- ☐ Not sure (28)

Q944 If "other," please describe:

_____

Q945 When did this injury occur?

- ○ Middle School or earlier (1)
- ○ Freshman High School (2)
- ○ Sophomore High School (3)
- ○ Junior High School (4)
- ○ Senior High School (5)
- ○ 1st year undergraduate (6)
- ○ 2nd year undergraduate (7)
- ○ 3rd year undergraduate (8)
- ○ 4th year undergraduate (9)
- ○ 5th year or more undergraduate (10)
- ○ Graduate or professional (11)

Q946 How many days total, were you absent from training or participation in competition due to this injury?

- 1 week or less (1)
- between 1-2 weeks (2)
- greater than 2 but less than 1 month (3)
- greater than 1 month but less than 2 months (5)
- greater than 2 months but less than 4 months (6)
- greater than 4 months but less than 6 months (7)
- greater than 6 months (8)
- Indefinitely (9)
- I currently have this injury (10)

Q947 Did you have an additional injury? ("No" will take you to the next section)

- Yes (1)
- No (3)

description 3

Now we will ask you about your menstrual periods. Please answer to the best of your knowledge.

Q52 At what age did you have your first period? (If you can not remember, please provide your best estimate).

If you have not experienced your first period please skip this question.

	0 3 7 10 13 17 20 23 27 30
Age ()	

Q53 Did your first menstrual period come naturally (by itself?)

- ○ Yes (1)
- ○ No (2)
- ○ I don't remember (3)
- ○ I have not had my first period (5)

Q53a If no, what was used to start your menstrual cycle? (Select all that apply)

- ☐ Reduced exercise (1)
- ☐ Weight gain (2)
- ☐ Hormones (birth control) (3)
- ☐ Other (4) _____

Q57 Do you **currently** experience a menstrual flow?

- ○ Yes (1)
- ○ No (2)
- ○ No, I am currently pregnant (3)

Q54
Have you had a period bleed *about* once a month since your first menstrual period?

- ○ Yes (1)
- ○ No (2)
- ○ Not sure (3)

Q56 If no, during what years have you missed more than 3 menstrual cycles in a row? (Select all that apply)

- ☐ Currently happening (12)
- ☐ Middle School or earlier (1)
- ☐ Freshman High School (2)
- ☐ Sophmore High School (3)
- ☐ Junior High School (4)
- ☐ Senior High School (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year undergraduate (10)
- ☐ Graduate or professional (11)

Q259 If no, during what years have you missed more than 6 menstrual cycles in a row? (Select all that apply)

- ☐ Currently happening (12)
- ☐ Middle School or earlier (1)
- ☐ Freshman High School (2)
- ☐ Sophmore High School (3)
- ☐ Junior High School (4)
- ☐ Senior High School (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year undergraduate (10)
- ☐ Graduate or professional (11)

Q55 What is the **greatest amount of time you have ever gone** without a menstrual flow (or "period")?

0 1 1 2 3 3 4 5 5 6 7 7 8 9 9 10111112

Months ()	
Years ()	

Q58 On average, **how many days are there in your typical menstrual cycle**, that is, from the beginning of bleeding of one menstrual period to the beginning of bleeding of the next period?

- Less than 20 days (1)
- 21-35 days (2)
- 35-60 days (3)
- 61-91 days (4)

Q59 **How long does your menstrual flow usually last**, that is from time bleeding began until is stopped completely? By "usually" we mean at least half of the time.

- 1-2 days (1)
- 3-7 days (2)
- More than 7 days (3)

Q60 Do you bleed or spot between your periods more than half of the time?

- Yes (1)
- No (2)

Q61 Have you ever been unable to predict when your menstrual cycle will come, that is, from the beginning of bleeding of one menstrual period to the beginning of bleeding of the next period?

- Yes (1)
- No (2)

Q63 Have you **ever** used birth control or contraception?

- ○ Yes (1)
- ○ No (2)

Q63a If yes, for how long (years, months) have you used contraceptives, in total? (months and/or years)

	0 1 2 4 5 6 7 8 10 11 12
Months ()	
Years ()	

Q263 If yes, during which yers have you **used** birth control or contraception? (Select all that apply)

- ☐ Middle School or earlier (4)
- ☐ Freshman High School (5)
- ☐ Sophmore High School (6)
- ☐ Junior High School (7)
- ☐ Senior High School (8)
- ☐ 1st year undergraduate (9)
- ☐ 2nd year undergraduate (10)
- ☐ 3rd year undergraduate (11)
- ☐ 4th year undergraduate (12)
- ☐ 5th year undergraduate (13)
- ☐ Graduate or professional (14)

Q64 Are you **currently** using birth control or contraception?

- ○ Yes (1)
- ○ No (2)

Q65
Select the primary purpose(s) for using birth control or contraception, **currently**? (check all that apply)

- ☐ Pregnancy prevention (1)
- ☐ Amenorrhea (loss of period for > 3 months) (2)
- ☐ Oligomenorrhea (irregular periods) (3)
- ☐ Acne treatment (4)
- ☐ PMS symptoms (5)
- ☐ Low bone density (6)
- ☐ Other (7) _____

Q66 If yes, what type(s) of birth control or contraception are you using **currently**? (select all that apply)

- ☐ Oral birth control pill (OCP) (1)
- ☐ IUD (copper) (2)
- ☐ IUD (hormonal like Mirena) (3)
- ☐ The Ring (Vaginal contraceptive) (4)
- ☐ Patch (transdermal contraceptive) (5)
- ☐ Condoms (6)
- ☐ Other (7) _____

Q67 What other forms of birth control or contraception have you used in the **past**? (select all that apply)

- ☐ N/A (1)
- ☐ Oral birth control pill (OCP) (2)
- ☐ IUD (copper) (3)
- ☐ IUD (hormonal like Mirena) (4)
- ☐ The Ring (Vaginal contraceptive) (5)
- ☐ Patch (transdermal contraceptive) (6)
- ☐ Condoms (7)
- ☐ Other (8) _____

Q260
Select the primary purpose(s) for using birth control or contraceptives **in the past**? (check all that apply)

- ☐ Pregnancy prevention (1)
- ☐ Amenorrhea (loss of period for > 3 months) (2)
- ☐ Oligomenorrhea (irregular periods) (3)
- ☐ Acne treatment (4)
- ☐ PMS symptoms (5)
- ☐ Low bone density (6)
- ☐ Other (7) _____

Q70 We would like to understand how your weight may have fluctuated over the years. Please provide your **in-season/race weight** for all years that apply.

We encourage you to use medical records or training logs as a reference if possible (or answer to the best of your memory).

	Weight (lbs.) (1)	Height (ft, inches) (2)
Age 16 (1)		
1st year undergraduate (2)		
2nd year undergraduate (3)		
3rd year undergraduate (4)		
4th year undergraduate (5)		
5th year undergraduate/ graduate school (6)		

Q71 Over the course of an average racing season:

- ○ I maintain my weight (1)
- ○ I lose weight (2)
- ○ I gain weight (3)
- ○ I don't know (4)

Q72 Please answer the following questions to reflect the previous 28 days...

	Always (1)	Usually (2)	Often (3)	Sometimes (4)	Rarely (5)	Never (6)
I eat sweets and carbohydrates without feeling nervous (2)	○	○	○	○	○	○
I think about dieting (7)	○	○	○	○	○	○
I feel extremely guilty after overeating (8)	○	○	○	○	○	○
I am terrified of gaining weight (9)	○	○	○	○	○	○
I exaggerate or magnify the importance of weight (10)	○	○	○	○	○	○
I am preoccupied with the desire to be thinner (11)	○	○	○	○	○	○
If I gain a pound, I worry that I will keep gaining weight (12)	○	○	○	○	○	○

Q79 Please answer the following questions to reflect the previous 28 days...

	Definitely true (1)	Mostly true (2)	Mostly false (3)	Definitely false (4)
I consciously hold back at meals in order not to gain weight (1)	○	○	○	○
I deliberately take small helpings as means of controlling my weight (2)	○	○	○	○
I do not eat some foods because they make me fat (3)	○	○	○	○

Q82 On a scale of 1 to 8, where 1 means no restraint in eating and 8 means total restraint, what number would you give yourself?

	0 1 2 3 4 5 6 7 8
Restraint ()	

Q83 How likely are you to consciously eat less than you want

- ○ Almost never (1)
- ○ Seldom (2)
- ○ Moderately likely (3)
- ○ Almost always (4)

Q84 How frequently do you avoid 'stocking up' on tempting foods (by "stocking up" we mean purchasing several servings to have at home)

- Almost never (1)
- Seldom (2)
- Moderately likely (3)
- Almost always (4)

Q85 Please indicate your level of agreement with the following statements.

	Always (11)	Most of the time (12)	About half the time (13)	Sometimes (14)	Never (15)
Only outstanding performance is good enough for my family (12)					
As a child, I tried very hard to avoid disappointing my parents and teachers (13)					
I hate being less than best at things (14)					
My parents expect excellence of me (15)					
I feel that I must do things perfectly or not do them at all (16)					
I have extremely high goals (17)					

Q69 How do you perceive your weight, compared to teammates and competitors?

- ○ Very overweight (1)
- ○ Overweight (2)
- ○ Normal weight (3)
- ○ Underweight (4)
- ○ Very underweight (5)

Q574 How do you perceive your weight, compared to the general population?

- ○ Very overweight (1)
- ○ Overweight (2)
- ○ Normal weight (3)
- ○ Underweight (4)
- ○ Very underweight (5)

Q263 **We will now ask you about your physical health.**

Q49 I seem to get sick more often than others

- ○ Strongly Agree (1)
- ○ Agree (2)
- ○ Neutral (3)
- ○ Somewhat disagree (4)
- ○ Strongly disagree (5)

description 10 **Please indicate the response that most accurately describes your situation.**

Q113 Do you feel gaseous or bloated in your abdomen when you do not have your period?

- Yes, several times a day (1)
- Yes, several times a week (2)
- Yes, once or twice a week or more seldom (3)
- Rarely or never (4)

Q114 Do you get cramps or stomach aches that cannot be related to menstruation?

- Yes, several times a day (1)
- Yes, several times a week (2)
- Yes, once or twice a week or more seldom (3)
- Rarely or never (4)

Q115 How often do you have bowel movements on average?

- Several times a day (1)
- Once a day (2)
- Once every other day (3)
- Twice a week (4)
- Once a week or more rarely (5)

Q116 How would you describe your stool?

- Normal (soft) (1)
- Diarrhea-like (watery) (2)
- Hard and dry (3)

Q468 Now we will ask you to recall your personal medical diagnoses. Have you been diagnosed with any of the following by a healthcare provider:

Q453 Have you ever been diagnosed with Polycystic Ovarian Syndrome (PCOS)?

- ○ Yes (1)
- ○ No (2)

Q91a If yes, when were you diagnosed with PCOS?

- ○ Middle school or earlier (1)
- ○ Freshman in high school (2)
- ○ Sophomore in high school (3)
- ○ Junior in high school (4)
- ○ Senior in high school (5)
- ○ 1st year undergraduate (6)
- ○ 2nd year undergraduate (7)
- ○ 3rd year undergraduate (8)
- ○ 4th year undergraduate (9)
- ○ 5th year or more undergraduate (10)
- ○ Graduate or professional (11)

Q454 Have you ever been diagnosed with Primary Ovarian Failure?

- ○ Yes (1)
- ○ No (2)

Q92a If yes, when were you diagnosed with Primary Ovarian Failure?

- ○ Middle school or earlier (1)
- ○ Freshman in high school (2)
- ○ Sophomore in high school (3)
- ○ Junior in high school (4)
- ○ Senior in high school (5)
- ○ 1st year undergraduate (6)
- ○ 2nd year undergraduate (7)
- ○ 3rd year undergraduate (8)
- ○ 4th year undergraduate (9)
- ○ 5th year or more undergraduate (10)
- ○ Graduate or professional (11)

Q455 Have you ever been diagnosed with Hirsutism?

- ○ Yes (1)
- ○ No (2)

Q93a If yes, when were you diagnosed with Hirsutism?

- ○ Middle school or earlier (1)
- ○ Freshman in high school (2)
- ○ Sophomore in high school (3)
- ○ Junior in high school (4)
- ○ Senior in high school (5)
- ○ 1st year undergraduate (6)
- ○ 2nd year undergraduate (7)
- ○ 3rd year undergraduate (8)
- ○ 4th year undergraduate (9)
- ○ 5th year or more undergraduate (10)
- ○ Graduate or professional (11)

Q456 Have you ever been diagnosed with Cushing's syndrome?

- ○ Yes (1)
- ○ No (2)

Q94a If yes, when were you diagnosed with Cushing's syndrome?

- ○ Middle school or earlier (1)
- ○ Freshman in high school (2)
- ○ Sophomore in high school (3)
- ○ Junior in high school (4)
- ○ Senior in high school (5)
- ○ 1st year undergraduate (6)
- ○ 2nd year undergraduate (7)
- ○ 3rd year undergraduate (8)
- ○ 4th year undergraduate (9)
- ○ 5th year or more undergraduate (10)
- ○ Graduate or professional (11)

Q457 Have you ever been diagnosed with Anorexia Nervosa?

- ○ Yes (1)
- ○ No (2)

Q95a If yes, when were you diagnosed with Anorexia Nervosa?

- ○ Middle school or earlier (1)
- ○ Freshman in high school (2)
- ○ Sophomore in high school (3)
- ○ Junior in high school (4)
- ○ Senior in high school (5)
- ○ 1st year undergraduate (6)
- ○ 2nd year undergraduate (7)
- ○ 3rd year undergraduate (8)
- ○ 4th year undergraduate (9)
- ○ 5th year or more undergraduate (10)
- ○ Graduate or professional (11)

Q458 Have you ever been diagnosed with Bulimia Nervosa?

- ○ Yes (1)
- ○ No (2)

Q96a If yes, when were you diagnosed with Bulimia Nervosa?

- ○ Middle school or earlier (1)
- ○ Freshman in high school (2)
- ○ Sophomore in high school (3)
- ○ Junior in high school (4)
- ○ Senior in high school (5)
- ○ 1st year undergraduate (6)
- ○ 2nd year undergraduate (7)
- ○ 3rd year undergraduate (8)
- ○ 4th year undergraduate (9)
- ○ 5th year or more undergraduate (10)
- ○ Graduate or professional (11)

Q459 Have you ever been diagnosed with Binge Eating Disorder?

- ○ Yes (1)
- ○ No (2)

Q97a If yes, when were you diagnosed with Binge Eating Disorder?

- ○ Middle school or earlier (1)
- ○ Freshman in high school (2)
- ○ Sophomore in high school (3)
- ○ Junior in high school (4)
- ○ Senior in high school (5)
- ○ 1st year undergraduate (6)
- ○ 2nd year undergraduate (7)
- ○ 3rd year undergraduate (8)
- ○ 4th year undergraduate (9)
- ○ 5th year or more undergraduate (10)
- ○ Graduate or professional (11)

Q460 Have you ever been diagnosed with Other Specified Feeding or Eating Disorder (OSFED)?

- ○ Yes (1)
- ○ No (2)

Q98a If yes, when were you diagnosed Other Specified Feeding or Eating Disorder (OSFED)?

- ○ Middle school or earlier (1)
- ○ Freshman in high school (2)
- ○ Sophomore in high school (3)
- ○ Junior in high school (4)
- ○ Senior in high school (5)
- ○ 1st year undergraduate (6)
- ○ 2nd year undergraduate (7)
- ○ 3rd year undergraduate (8)
- ○ 4th year undergraduate (9)
- ○ 5th year or more undergraduate (10)
- ○ Graduate or professional (11)

Q461 Have you ever been diagnosed with Anxiety?

- ○ Yes (1)
- ○ No (2)

Q99a If yes, when were you diagnosed with Anxiety?

- ○ Middle school or earlier (1)
- ○ Freshman in high school (2)
- ○ Sophomore in high school (3)
- ○ Junior in high school (4)
- ○ Senior in high school (5)
- ○ 1st year undergraduate (6)
- ○ 2nd year undergraduate (7)
- ○ 3rd year undergraduate (8)
- ○ 4th year undergraduate (9)
- ○ 5th year or more undergraduate (10)
- ○ Graduate or professional (11)

Q462 Have you ever been diagnosed with Depression?

- ○ Yes (1)
- ○ No (2)

Q100a If yes, when were you diagnosed Depression?

- ○ Middle school or earlier (1)
- ○ Freshman in high school (2)
- ○ Sophomore in high school (3)
- ○ Junior in high school (4)
- ○ Senior in high school (5)
- ○ 1st year undergraduate (6)
- ○ 2nd year undergraduate (7)
- ○ 3rd year undergraduate (8)
- ○ 4th year undergraduate (9)
- ○ 5th year or more undergraduate (10)
- ○ Graduate or professional (11)

Q463 Have you ever been diagnosed with Obsessive Compulsive Disorder (OCD)?

- ○ Yes (1)
- ○ No (2)

Q101a If yes, when were you diagnosed Obsessive Compulsive Disorder (OCD)?

- ○ Middle school or earlier (1)
- ○ Freshman in high school (2)
- ○ Sophomore in high school (3)
- ○ Junior in high school (4)
- ○ Senior in high school (5)
- ○ 1st year undergraduate (6)
- ○ 2nd year undergraduate (7)
- ○ 3rd year undergraduate (8)
- ○ 4th year undergraduate (9)
- ○ 5th year or more undergraduate (10)
- ○ Graduate or professional (11)

Q464 Have you ever been diagnosed with Low Bone Mineral Density?

- ○ Yes (1)
- ○ No (2)

Q102a If yes, when were you diagnosed Low Bone Mineral Density?

- ○ Middle school or earlier (1)
- ○ Freshman in high school (2)
- ○ Sophomore in high school (3)
- ○ Junior in high school (4)
- ○ Senior in high school (5)
- ○ 1st year undergraduate (6)
- ○ 2nd year undergraduate (7)
- ○ 3rd year undergraduate (8)
- ○ 4th year undergraduate (9)
- ○ 5th year or more undergraduate (10)
- ○ Graduate or professional (11)

descriptive 9 **Please indicate if you have experienced any of the following**

Q103 Ever had abnormal thyroid function test results.

- ○ Yes (1)
- ○ No (2)

Q103a When did this occur (select all)?

- ☐ Middle school or earlier (1)
- ☐ Freshman in high school (2)
- ☐ Sophomore in high school (3)
- ☐ Junior in high school (4)
- ☐ Senior in high school (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional (11)

Q104 Ever had a low resting metabolic rate

- ○ Yes (1)
- ○ No (2)

Q104a When did this occur (select all)?

- ☐ Middle school or earlier (1)
- ☐ Freshman in high school (2)
- ☐ Sophomore in high school (3)
- ☐ Junior in high school (4)
- ☐ Senior in high school (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional (11)

Q105 Ever had a history of anemia, low hemoglobin, iron or ferritin, and/or abnormal bruising

- ○ Yes (1)
- ○ No (2)

Q105a When did this occur (select all)?

- ☐ Middle school or earlier (1)
- ☐ Freshman in high school (2)
- ☐ Sophomore in high school (3)
- ☐ Junior in high school (4)
- ☐ Senior in high school (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional (11)

Q106 Fell below normal growth curves during childhood (as indicated by doctor)

- ○ Yes (1)
- ○ No (2)

Q106a When did this occur (select all)?

- ☐ Middle school or earlier (1)
- ☐ Freshman in high school (2)
- ☐ Sophomore in high school (3)
- ☐ Junior in high school (4)
- ☐ Senior in high school (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional (11)

Q107 Ever passed out or nearly passed out during or after exercise

- ○ Yes (1)
- ○ No (2)

Q107a When did this occur (select all)?

- ☐ Middle school or earlier (1)
- ☐ Freshman in high school (2)
- ☐ Sophomore in high school (3)
- ☐ Junior in high school (4)
- ☐ Senior in high school (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional (11)

Q108 Ever had discomfort, pain, or pressure in your chest during exercise

- ○ Yes (1)
- ○ No (2)

Q108a When did this occur (select all)?

- ☐ Middle school or earlier (1)
- ☐ Freshman in high school (2)
- ☐ Sophomore in high school (3)
- ☐ Junior in high school (4)
- ☐ Senior in high school (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional (11)

Q109 Heart ever raced or skipped beats during exercise

- ○ Yes (1)
- ○ No (2)

Q109a When did this occur (select all)?

- ☐ Middle school or earlier (1)
- ☐ Freshman in high school (2)
- ☐ Sophomore in high school (3)
- ☐ Junior in high school (4)
- ☐ Senior in high school (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional (11)

Q110 A doctor has ever ordered a heart test for you (EKG, ECG, echocardiogram)

- ○ Yes (1)
- ○ No (2)

Q110a When did this occur (select all)?

- ☐ Middle school or earlier (1)
- ☐ Freshman in high school (2)
- ☐ Sophomore in high school (3)
- ☐ Junior in high school (4)
- ☐ Senior in high school (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional (11)

Q111 You get lightheaded or feel shorter of breath than expected during exercise

- ○ Yes (1)
- ○ No (2)

Q111a When did this occur (select all)?

- ☐ Middle school or earlier (1)
- ☐ Freshman in high school (2)
- ☐ Sophomore in high school (3)
- ☐ Junior in high school (4)
- ☐ Senior in high school (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional (11)

Q112 You get more tired or short of breath more quickly than teammates during exercise

- ○ Yes (1)
- ○ No (2)

Q112a When did this occur (select all)?

- ☐ Middle school or earlier (1)
- ☐ Freshman in high school (2)
- ☐ Sophomore in high school (3)
- ☐ Junior in high school (4)
- ☐ Senior in high school (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional (11)

Q117-Q123 **Over the last 2 weeks, how often have you been bothered by the following problems?**

	Not at all (1)	Several days (2)	Over half the days (3)	Nearly every day (4)
Feeling nervous, anxious, or on edge (1)	○	○	○	○
Not being able to stop or control worrying (2)	○	○	○	○
Worrying too much about different things (3)	○	○	○	○
Trouble relaxing (4)	○	○	○	○
Being so restless that it's hard to sit still (5)	○	○	○	○
Becoming easily annoyed or irritable (6)	○	○	○	○
Feeling afraid as if something awful might happen (7)	○	○	○	○

Q124-Q131 Over the last 2 weeks, how often have you been bothered by any of the following:

	Not at all (1)	Several days (2)	More than half the days (3)	Nearly every day (4)
Little interest or pleasure in doing things (1)	○	○	○	○
Feeling down, depressed, or hopeless (2)	○	○	○	○
Trouble falling or staying asleep, or sleeping too much (3)	○	○	○	○
Feeling tired or having little energy (4)	○	○	○	○
Poor appetite or overeating (5)	○	○	○	○
Feeling bad about yourself or that you are a failure or have let yourself or your family down (6)	○	○	○	○
Trouble concentrating on things, such as reading the newspaper or watching tv (7)	○	○	○	○
Moving or speaking so slowly that other people could have noticed. Or the opposite being so fidgety or restless that you have been moving around a lot more than usual (8)	○	○	○	○

Q132 If you checked off any problems, how difficult Not difficult at all have these problems made it for you to do your work, take care of things at home, or get along with other people?

- ○ Not difficult at all (1)
- ○ Somewhat difficult (2)
- ○ Very difficult (3)
- ○ Extremely difficult (4)

Q465 Please indicate the following regarding your feelings.

	Almost never (1)	Sometimes (2)	About half the time (3)	Most of the time (4)	Almost always (5)
I pay attention to how I feel (1)	○	○	○	○	○
I am attentive to my feelings (2)	○	○	○	○	○
When I'm upset, I acknowledge my emotions (3)	○	○	○	○	○
I have no idea how I am feeling (4)	○	○	○	○	○
I have difficulty making sense out of my feelings. (5)	○	○	○	○	○
I am confused about how I feel (6)	○	○	○	○	○
When I'm upset, I become out of control (7)	○	○	○	○	○
When I'm upset, I have difficulty controlling my behaviors (8)	○	○	○	○	○
When I'm upset, I lose control over my behaviors (9)	○	○	○	○	○

We will now ask you sensitive questions about trauma. Please indicate your past experiences as you feel comfortable.

Q142 Have you ever experienced any type (emotional, physical, or sexual) of abuse (either from someone you know or don't know)?

- ○ Yes (1)
- ○ No (2)

Q142a If yes, have you experienced emotional abuse?

- ○ Yes (1)
- ○ No (2)

Q142abc.i If yes, can you recall when?

- ☐ Middle School or earlier (1)
- ☐ Freshman High School (2)
- ☐ Sophomore High School (3)
- ☐ Junior High School (4)
- ☐ Senior High School (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional (11)
- ☐ Not sure (12)

Q142b If yes, have you experienced physical abuse?

- ○ Yes (1)
- ○ No (2)

Q142abc.i If yes, can you recall when?

- ☐ Middle School or earlier (1)
- ☐ Freshman High School (2)
- ☐ Sophomore High School (3)
- ☐ Junior High School (4)
- ☐ Senior High School (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional (11)
- ☐ Not sure (12)

Q142c If yes, have you experienced sexual abuse?

- ○ Yes (1)
- ○ No (2)

Q142abc.i If yes, can you recall when?

- ☐ Middle School or earlier (1)
- ☐ Freshman High School (2)
- ☐ Sophomore High School (3)
- ☐ Junior High School (4)
- ☐ Senior High School (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional (11)
- ☐ Not sure (12)

descriptive 13 Please indicate the response that most accurately describes your experiences.

Q143 Have you ever seen a psychologist, psychiatrist, therapist, and/or counselor?

- ○ Yes (1)
- ○ No (2)

Q143a If yes, when (all that apply)

- ☐ Middle School or earlier (1)
- ☐ Freshman High School (2)
- ☐ Sophomore High School (3)
- ☐ Junior High School (4)
- ☐ Senior High School (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional (11)

Q143b If yes, for how long have you cumulatively seen a psychologist, psychiatrist, therapist, and/or counselor (including breaks)

- ○ One time (1)
- ○ Less than 3 months (2)
- ○ More than 3 months, but less than 6 months (3)
- ○ More than 6 months, but less than one year (4)
- ○ More than one year (5)

Q144 Have you ever seen a nutritionist or dietitian?

- ○ Yes (1)
- ○ No (2)

Q144a If yes, when? (select all that apply)

- ☐ Middle School or earlier (1)
- ☐ Freshman High School (2)
- ☐ Sophomore High School (3)
- ☐ Junior High School (4)
- ☐ Senior High School (5)
- ☐ 1st year undergraduate (6)
- ☐ 2nd year undergraduate (7)
- ☐ 3rd year undergraduate (8)
- ☐ 4th year undergraduate (9)
- ☐ 5th year or more undergraduate (10)
- ☐ Graduate or professional (11)

Q144b If yes, for how long have you cumulatively seen a nutritionist or dietitian (including breaks)?

- ○ One time (1)
- ○ Less than 3 months (2)
- ○ More than 3 months, but less than 6 months (3)
- ○ More than 6 months, but less than one year (4)
- ○ More than one year (5)

Q145 Does your athletic department have a mental health professional(s) (psychologist, psychiatrist, therapist, and/or counselor) on staff?

- ○ Yes (1)
- ○ No (2)
- ○ Not sure (3)

Q146 Does your university's athletics department have a nutritionist or registered dietitian on staff?

- Yes (1)
- No (2)
- Not sure (3)

Q604 Comments on mental health and/or nutrition staff:

_____

_____

_____

descriptive 14 **These questions ask about your sexual desire during the <u>past 4 weeks.</u> Please answer the following questions as honestly and clearly as possible, and remember that your responses will be kept completely confidential.**

Q152 How often did you feel sexual desire or interest?

- Almost always or always (1)
- Most times (more than half the time) (2)
- Sometimes (about half the time) (3)
- A few times (less than half the time) (4)
- Almost never or never (5)

Q153 Over the past 4 weeks, how would you rate your level (degree) of sexual desire or interest?

- Very high (1)
- High (2)
- Moderate (3)
- Low (4)
- Very low or none at all (5)

Q154 Over the past 4 weeks, have you engaged in sexual activity or intercourse?

- Yes (1)
- No (2)

Q154a If yes, over the past 4 weeks, how would you rate your level of sexual arousal ("turn on") during sexual activity or intercourse?

- Very high (1)
- High (2)
- Moderate (3)
- Low (4)
- Very low or none at all (5)

Q154b Over the past 4 weeks, how difficult was it to become lubricated ("wet") during sexual activity or intercourse?

- Very high (1)
- High (2)
- Moderate (3)
- Low (4)
- Very low or none at all (5)

The following questions will ask you to consider your average sleep quality and level of fatigue.

Q155
During the recent past, how many hours of actual sleep did you get at night?

(This may be different than the number of hours you spent in bed).

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Hours ()	

Q156
How satisfied/dissatisfied are you with the quality of your sleep?

- ○ Very satisfied (1)
- ○ Somewhat satisfied (2)
- ○ Neither satisfied nor dissatisfied (3)
- ○ Somewhat dissatisfied (4)
- ○ Very dissatisfied (5)

Q157 How often do you have trouble staying asleep?

- ○ None (1)
- ○ Once or twice per week (2)
- ○ Three or four times per week (3)
- ○ Five to seven times per week (4)

Q158 During the recent past, how often have you taken medicine to help you sleep (prescribed or over-the-counter)?

- ○ None (1)
- ○ Once or twice per week (2)
- ○ Three or four times per week (3)
- ○ Five to seven times per week (4)

Q159 I feel overly tired from my sport participation

- Almost never (1)
- Rarely (2)
- Sometimes (3)
- Often (4)
- Almost always (5)

Q160 Hypothetically, if you did not have a regular menstrual cycle, would you be willing to gain 5-7 pounds in order to get it back?

- Yes (1)
- No (2)
- Not sure (3)

Q161 Hypothetically, if you did not have a regular menstrual cycle, would you be willing to eat more food to get it back?

- Yes (1)
- No (2)
- Not sure (3)

Q162 Hypothetically, if you did not have a regular menstrual cycle, would you be willing to decrease training volume to get it back?

- Yes (1)
- No (2)
- Not sure (3)

Q163 Average time I spend on social media **per day** (laptop and phone):

	0 6 12 18 24 30 36 42 48 54 60
Minutes ()	
Hours ()	

Q164 Did you use current and/or past training logs, food logs, and medical records on hand as a reference during the survey?

- ○ Yes (1)
- ○ No (2)

Q165 If yes, select all that apply:

- ☐ Training logs (2)
- ☐ Food logs (3)
- ☐ Medical records (4)
- ☐ Other (5) _____

Q201 Comments or Feedback

_____

_____

Q202 Thank you for your participation in this survey. Your support and honest answers are greatly appreciated! We greatly appreciate the time you have taken to contribute your experiences and look forward to hearing from you again in the future.